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STORAGE, DISTRIBUTION, AND DISPENSING OF AIRCRAFT AND AUTOMOTIVE FUELS

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DEPARTMENTS OF THE ARMY AND THE AIR FORCE

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DEPARTMENTS OF THE ARMY
AND THE AIR FORCE

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STORAGE, DISTRIBUTION, AND DISPENSING OF AIRCRAFT AND AUTOMOTIVE FUELS

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SECTION 1. INTRODUCTION

1-1. PURPOSE. This manual presents criteria and procedures for design of facilities for receiving, storing, distributing, and dispensing fuels needed for aircraft and vehicles operated by United States Army, Air Force, and Air National Guard units.

1-2. SCOPE. The provisions of this manual are applicable for all elements of the Army and the Air Force responsible for design of military construction.

1-3. STANDARD DRAWINGS AND TECHNICAL SPECIFICATIONS. The following standard drawings and technical specifications apply, for design of fuel facilities presented in this manual, and are available through U. S. Army, Corps of Engineers, division and district offices. Comments and suggestions for improving these designs, and for special applications, should be addressed
* to HQDA(DAEN-MCE-U) WASH DC 20314, or to HQ USAF/PREES WASH DC 20332.

Drawing Number	Structure
78-24-01	Standard Aircraft Refueling System, Multiple Outlet Hydrant Type.
78-24-0	Standard Aircraft Bulk Fuel Storage Underground - 10,000 Barrels Capacity.
78-24-05	Standard Aircraft Bulk Fuel Storage Underground - 20,000 Barrels Capacity.
78-24-06	Standard Aircraft Bulk Fuel Storage Underground - 50,000 Barrels Capacity.
78-24-07	Standard Aircraft Bulk Fuel Storage Underground - 80,000 Barrels Capacity.
78-24-08	Standard Aircraft Bulk Fuel Storage Underground - 100,000 Barrels Capacity.
78-24-09	Standard Aircraft Bulk Fuel Storage Aboveground - 10,000 Barrels Capacity.
78-24-10	Standard Aircraft Bulk Fuel Storage Aboveground - 25,000 Barrels Capacity.
78-24-11	Standard Aircraft Bulk Fuel Storage Aboveground - 55,000 Barrels Capacity.
78-24-12	Standard Aircraft Bulk Fuel Storage Aboveground - 80,000 Barrels Capacity.
78-24-13	Standard Aircraft Bulk Fuel Storage Aboveground - 100,000 Barrels Capacity.

(Continued)

Drawing Number	Structure
78-24-15	Standard Aircraft Bulk Fuel Storage Aboveground with Pontoon Floating Roof.
78-24-16	Standard Airbase Tank Farm Facilities to Supply Two Fuels to Hydrant Aircraft Refueling Systems.
78-24-17	Standard Airbase Tank Farm Facilities to Supply One Fuel to Hydrant Aircraft Refueling System.
78-24-18	Standard Air Base Tank Farm Facilities to Supply Aircraft Refueler Trucks.
78-24-19	Standard Aircraft Underground Bulk Fuel Storage Tank Fa
78-24-20	Standard Aircraft Fueling System for Army Aviation.
78-24-21	Hydrant Refueling Facilities, Atomic Blast Resistant Type
78-24-22	Air Base Tank Farm Facilities, Atomic Blast Protection for Pumphouse.
78-24-23	Standard Area Reserve Tank Farm.
78-24-24	Atomic Blast Protection for Refueling Facilities, Multiple Outlet Hydrant Type.
78-24-25	Area Reserve Tank Farm Facilities, Atomic Blast Resist
78-24-26	Standard Aircraft Refueling System, Multiple Outlet Mass Apron Parking.
78-24-27	Standard Aircraft Bulk Fuel Storage Aboveground Steel Ta with Floating Pan and Cone Roof.
* AW 78-24-28	Pressurized Hydrant Fueling System.
* AW 78-24-29	Pressurized Hot Fueling System.
* AW 78-24-30	Base Tank Farm.
* AW 78-24-31	Underground Steel Tanks.
* AW 78-24-32	Petroleum Operations Building.
78-25-01	Standard Bulk Alconol Storage and Water-Alcohol Blending System, Single Wing Base.

1-4. OPERATING AND MAINTENANCE MANUALS, PREPARATION. Guides for preparation of operating and maintenance manuals are available for the systems in drawings number 78-24-01; 78-24-15, -16, -17, -18; 78-24-19 and -20; 78-24-23; 78-24-26; and 78-25-01, from the same sourc as the drawings, listed in the preceding paragraph.

SECTION 2. CHARACTERISTICS OF PRODUCTS TO BE HANDLED, AND THEIR EFFECTS ON DESIGN

2-1. CLASSES. With the exception of methyl alcohol, the products to be handled at facilities covered by this manual are all classed as liquid hydrocarbons. Characteristics of these products, such as flammability, reactions to change in temperature, weight, viscosity, susceptibility to contamination, and contact effects on materials and personnel each require understanding if serious deficiencies in design are to be avoided.

2-2. FLAMMABILITY. Liquid hydrocarbons or alcohols will not burn or explode while in a liquid state but are classed as flammable liquids by fire-protection standards. This is because of their tendency to give off vapors at favoring temperatures, which will form a highly flammable and explosive mixture when combined with air in the proper proportions. Destructive pressures will be developed by the sudden combustion when such flammable mixtures are ignited within an inclosed space or container. In this connection, it should be noted that the vapors from these products are heavier than air and will tend to collect at the floor level of pumprooms and pits, or to "flow" along ground surfaces to low areas, unless dispersed by natural or mechanically produced air movement. The inherent tendency of a liquid to vaporize, the lowest temperature at which the liquid will give off sufficient vapors to form an ignitible mixture with air, the proportions by volume of the vapors required to support combustion, and the temperature needed to ignite the flammable mixture are each an indication of the relative fire or explosion hazard to be anticipated in the design of facilities for the storage and handling of flammable liquids.

a. Volatility. The tendency of a liquid to vaporize is known as volatility. The degree of volatility is reflected by the product's vapor pressure and its distillation range. Vapor pressure is the pressure generated by the product at certain temperatures. Vapor pressure referred to in specifications for these products is the pressure in pounds per square inch at 100°F. when tested by the Reid Method (Federal Standard Method No. 1201.6 of Federal Test Method Standard No. 791). Since the vapor pressure of a product increases as

the temperature of the product increases, products that release little or no vapors at moderate temperatures will become highly volatile when exposed to high ambient temperatures, as when spilled on hot surfaces such as exhaust pipes from fuel trucks. Figure No. 1 at the end of this section shows the variation of vapor pressure with temperature for different fuels. The distillation range of a product is defined by the temperature at which a liquid actively starts to vaporize and the temperature at which it has entirely vaporized. The former is called the initial boiling point and the latter the end point.

(1) Gasolines. Automotive vehicular gasolines have a low initial boiling point, about 100 degrees F., and a relatively high Reid vapor pressure, ranging from an allowable maximum by specifications of 8 p.s.i. for average-temperature grade to as high as 14 p.s.i. for cold-temperature grade. The initial boiling point for aviation gasoline is some 10 to 15 degrees higher, and Reid vapor pressure is limited by specifications to a maximum of 7 p.s.i. As a consequence, these fuels release large quantities of vapors at normal temperatures, and continue to release sufficient vapors to form an ignitible mixture at temperatures as low as minus 40 degrees F. Although the flashpoint of gasolines is very low, the high volatility makes this product relatively safe to handle in storage tanks since it can be reasonably assumed that, at sea-level pressure and at temperatures above plus 20 degrees F., the vapor-air mixtures in stationary gasoline tanks will be too rich to ignite, and the only hazard of fire will be ignition at the vent outlet where the mixture becomes diluted with outside air. At sea-level pressure, and at temperatures between plus 20 and minus 40 degrees F., it must be assumed that a flammable mixture is present within the tank. However, it should be assumed that a flammable mixture will always be present in the vicinity of leaking tanks or piping systems, or at locations where spillage has occurred. When it is recalled that the vapors from one gallon of gasoline will occupy between 20 and 25 cubic feet at atmospheric pressure, the importance of storing these products in closed containers and of insuring the discharge of vapors from storage tanks at locations where they will be dispersed before they can come in contact with any potential source of ignition is apparent.

(2) Kerosene, and kerosene-type jet-engine fuels. Kerosene and jet-aircraft engine fuels such as grade JP-1, which is a kerosene-type fuel now obsolete, and grade JP-5, which has been used in Navy aircraft, and JP-7, have high flashpoints, approximately as follows: kerosene 150 degrees F.; JP-1, 110 degrees; JP-5, 140 degrees, and JP-7, 150 degrees F. These are low-volatility fuels. Under normal temperatures and atmospheric pressures the vapor-and-air mixtures in the space above the liquid in closed tanks are too lean to support combustion. Under conditions of high altitudes and high temperatures, a flammable mixture may form in the tank. These liquids will ignite if spilled and spread thin on pavement or earth, or if heated sufficiently by an outside source. JP-7 fuel is highly refined, clear colorless (so-called "white"), thermally stable to withstand high temperatures in jet engine fuel systems at flight speed. Thermally unstable fuels in use for high-temperature jet engine fuel systems would produce coke that would plug engine manifolds and fuel jets, causing hot spots and consequent malfunction. For JP-7, special materials will be required.

(3) Gasoline-type jet-engine fuel. The difficulty of producing grade JP-1 fuel in sufficient quantitites, and its poor starting qualities, brought on the development and, for a time, wide use of grade JP-3, which was a blend of gasoline, kerosene, and light distillates. (Grade JP-2 was never produced in commercial quantitites.) The requirements for safe handling of this grade are quite comparable to those for gasoline, since the predominant hydrocarbons in grade JP-3 are those that predominate in gasoline. These hydrocarbons improved the starting quality of the fuel, but the Reid vapor pressure of 6 pounds per square inch permitted by specifications made this fuel unsuitable for high altitudes. Further research produced grade JP-4 fuel for use in most military aircraft.

(4) Grade JP-4 jet-engine fuel. Grade JP-4 fuel is also a blend of gasoline, kerosene, and light distillates, but the specification limitation to 2 to 3 p.s.i. Reid vapor pressure reduced the volatility to an acceptable range for high-rate-of-climb and high-altitude aircraft operation. From the standpoint of safe ground handling, however, the reduction in volatility substantially increased the hazard of fire or explosion. This is because JP-4 fuel contains enough of the gasoline hydrocarbons to give it the extremely low flashpoint of approximately 20 degrees below zero, Fahrenheit (minus-20 degrees, F.). This combination of low volatility and low flashpoints gives problems

in handling from the standpoint of the prevention of fire or explosion. Because of the low volatility, it cannot be assumed that vapor-air mixtures of JP-4 fuel in stationary tanks will be too rich to ignite at sea-level pressure until the temperature reaches plus 80 degrees F. or higher. On the other hand, it must be assumed that such mixtures will be flammable at sea-level pressure between temperatures of plus 80 and minus 35 degrees F. In the latter case, any ignition at vent outlets will travel into the tank and cause violent combustion. Removal of any source of ignition from the vicinity of such vent outlets, or filler openings of tank cars or tank trucks, is of urgent importance when this fuel is being handled. JP-4 is subject to the ignition of its flammable vapor-air mixtures by the discharg of static electricity generated by the flow of the fuel in pipes. This condition occurs when a fuel is being delivered into a tank, the charge moving from the fuel toward the walls and bottom of the tank and toward the liquid-air surface. Where there is complete continuity between the roof structure, the shell plates, bottom plates and floating pan or pontoon roof, the steel tank safely conducts to the ground the charges that reach it. The charges reaching the liquid-air surfaces, if built up to a sufficient potential, will spark over to the nearest metal conductor, the velocity at which the fuel enters the tank and the rapidity with which the charge reaches the surface having a great deal to do with the creation of the spark. Where fuels such as gasoline give off large quantities of vapo at the surface during filling, and form mixtues too rich to burn, thi phenomenon has caused no harm. On the other hand, where explosive mixture are formed at the liquid surface, severe explosions have occurred. Explosions of this nature have occurred when JP-4 fuel was being delivered at high flow rates into empty tanks, or tanks that have been purged of hig concentrations of gasoline vapors and air mixtures. The recommended practice is to initially fill the tank at a flow rate not exceeding a velocity of 3 feet per second until the fill nozzle is submerged or until the floating pan or roof is afloat. Small amounts of entrained water are credited with causing greater static charges to accumulate on the free surface of an oil during high-velocity filling. Because of this phenomenon, the use of water slugs to separate cargoes of JP-4 and gasoline in multi-products pipelines will not be permitted. Leakage or spillage of JP-4 fuel presents the hazard of the formation of flammable mixtures and, because of the somewhat slower evaporation rate, for longer periods than for gasoline. This is particularly true where the liquid is spread thin over a floor or pavement

where contact with flame for just an instant will start a fire in almost any flammable liquid regardless of its volatility.

(5) Diesel-engine fuels. Fuel oils used in diesel engines are low-volatility fuels and have flashpoints ranging from 110 to 140 degrees F., depending on the specification and class, and can be regarded as corresponding to the kerosene and kerosene-type fuels with regard to relative flammability.

(6) Methyl alcohol. Methyl alcohol, which is blended with water and injected into the fuel systems of certain piston-type engines and the after burners of gas-turbine jet-aircraft engines for power augmentation, is produced in commercial quantities under the chemical name of Methanol through the oxidation of hydrocarbon gases to exacting formula. Methyl alcohol has a Reid vapor pressure of slightly over 2 p.s.i. and a relatively high boiling point approximating 150 degrees F. As a consequence, this product does not tend to give off large quantities of vapors at average temperatures, and ceases to give off sufficient vapors to support combustion at between 50 and 60 degrees F. Storage of this product in underground tanks at most locations will tend to insure that the vapor-air mixture within the tank will be too lean to support combustion. Because of the comparatively wide flammable range, between 6 percent and 36.5 percent of its vapors in air, a flammable mixture is more likely to be present when temperatures are high enough to cause release of quantities of this product's vapors. Leakage or spillage of alcohol on warm surfaces will always result in the formation of a flammable mixture. The wide flammable range makes methyl alcohol fires more difficult than gasoline fires to control with CO_2 or foam extinguishers because of the smaller percentages of air required to support combustion. Methyl alcohol's solubility in water is important, not only because fires in liquids soluble in water can be extinguished with water by a combination of dilution and cooling, but also because a small amount of dissolved water tends to reduce the hazard of static electricity. Alcohol-water blends should be regarded as flammable because sufficient heating of these solutions will cause release of dangerous quantities of flammable vapors.

b. Flashpoint. The lowest temperature at which a flammable liquid will give off sufficient vapors to form an ignitible mixture with air is known as the liquid's flashpoint. The flashpoint for liquid hydrocarbon mixtures can be calculated with a reasonable degree of accuracy by determining the product's initial boiling point in degrees F. and subtracting 122 from 0.73 of this temperature. Thus, a gasoline with an initial boiling point of 100 degrees F. would have a flashpoint approximating (100 x 0.73) -122, or minus 49 degrees F. The actual flashpoint of a liquid having a flashpoint below 175 degrees F. is determined by the Tag Closed Tester, and for a liquid having a flashpoint of 175 degrees F or higher is determined by the Pensky-Martens Closed Tester (Federal Standard Methods No. 1101.7 and No. 1102.10, respectively, of Federal Test Method Standard No. 791). The Factory Insurance Association divides flammable liquids into two classes according to their closed-tester flashpoints; those with flashpoints below 110 degrees F. being regarded as more hazardous, and those with flashpoints above 110 degrees F. being regarded as relatively safe. This organization, however, points to the increasing hazards of the latter when exposed to high ambient temperatures.

c. Flammable Range. The relative hazard of a flammable liquid may be judged by the lowest percentage by volume of the liquid's vapors in air needed to make the mixture flammable, and the range between this percentage and the highest percentage by volume of the liquids in air that will leave sufficient air to support combustion. Mixtures below the lower limit are "too lean" to burn, while those above the upper limit are "too rich" to burn. The broader the range, the easier it is to create a flammable mixture. Normally, liquids with narrow flammable ranges and higher B.t.u. conten per pound create more violent combustions than liquids with wide flammable limits and lower B.t.u. content per pound. For example, gasoline has a flammable range of from slightly above 1 percent to between 6 and 8.5 percent, whereas methyl alcohol has a range of approximately 6 percent to between 36 and 37 percent. Thus, while it is easier to create a flammable mixture with methyl alcohol, an explosion involving gasoline would be more violent. Flammable limits listed in most common sources are given at room temperature, except when the flashpoint is above room temperature. In such cases

the flammable limits are determined at or above the flashpoint temperature. In all cases, the flammable range widens as the temperature increases, so that when ignition temperature is reached, the lower limit approaches zero and the upper limit approaches 100 percent.

d. Ignition Temperatures. The ignition temperature is the lowest temperature to which a flammable mixture must be heated before it will ignite. Any flame, an electric spark of sufficient energy, or any body that has been heated to the required temperature will ignite the mixture. The ignition temperature of automotive gasoline is about 560 degrees F.; methyl alcohol about 878 degrees F.; JP-4 fuel about 490 degrees F.; aviation gasoline about 840 degrees F.; and No. 2 heating oil about 500 degrees F. Ignition temperatures of other hydrocarbon products are listed in the National Fire Codes published by the National Fire Protection Association.

2-3. LIQUID EXPANSION. When confined in pipes, hose lines, or nonvented containers, and subjected to rising temperatures, all of these products will expand and create pressures capable of bursting the container unless provisions for the relief of this pressure are incorporated in the design. Such provisions must include pressure-relief-bypass piping around all normally closed valves so that excessive pressure resulting from product expansion will be relieved to the storage tank. Similar provisions must be made for relief of excessive pressures from filter/separators, and other pressure vessels.

2-4. LIQUID WEIGHT. The weight of a liquid must be considered when determining loads to be supported by tank foundations and supports for piping. A liquid's weight has a direct relation to the horsepower needed to drive pumping units, and to the design of tank foundations and pipe supports. In these cases, it will be wise to assume the maximum weight permitted by specifications under which the product is purchased, and to consider the possibility of future switch-over of the system to a heavier product. A liquid's relative weight may be expressed in terms of density, specific gravity, or degrees A.P.I. (American Petroleum Institute).

a. Density. The density of a liquid is its weight in pounds per cubic foot of volume. Conversely, the specific volume of a liquid is the cubic feet of space occupied by

one pound of the liquid. If the specific gravity of the liquid is known, the density at 60°F. in pounds per cubic foot will be equal to 62.37 x specific gravity. The density of a liquid may also be expressed in terms of grams of weight per cubic centimeter of volume.

<u>b</u>. <u>Specific Gravity</u>. Specific gravity is the term indicating the density of a liquid with reference to water, which is given a specific gravity rate of 1.00. A liquid lighter than water will have a specific gravity below 1.00 while a liquid heavier than water will have a specific gravity of more than 1.00. The comparison is usually based on a temperature of 60°F. for the liquid and the water, and is expressed as specific gravity (60°F./60°F.). The specific gravity for any liquid can be found by comparing the weight of equal volumes of the liquid and water, or by means of a hydrometer.

(1) By weight comparison.

$$\text{Specific Gravity (60°F./60°F.)} = \frac{\text{Wt. of 1 gal. of the liquid}}{8.33}$$

$$\text{Specific Gravity (60°F./60°F.)} = \frac{\text{Wt. of 1 cu. ft. of the liquid}}{62.37}$$

(2) By hydrometer.

(a) A.P.I. scale. For oils the scale is graduated in degrees A.P.I., a scale developed by the American Petroleum Institute. The relations between degrees A.P.I. and specific gravity are based on the following formula:

$$\text{Specific Gravity (60°F./60°F.)} = \frac{141.5}{131.5 + \text{degrees A.P.I.}}$$

(b) Baumé scale. This scale is used for liquids lighter or heavier than water. The relations between degrees Baumé and specific gravity are based on the following formulas:

$$\text{Specific gravity for liquids lighter than water} = \frac{140}{130 + \text{degrees Baumé}}$$

$$\text{Specific gravity for liquids heavier than water} = \frac{145}{145 - \text{degrees Baume'}}$$

Figure No. 2 at the end of this section shows the variation of specific gravity with temperature for the various fuels most commonly used by the military services.

Figure 3 shows relations between specific gravity, degrees A.P.I., weight in pounds per gallon, and pounds per cubic foot.

2-5. VISCOSITY. Viscosity is a measure of the internal friction of a liquid tending to resist flow. It varies greatly with different liquids and decreases with rising temperature. Liquids such as water and aircraft engine fuels have relatively low viscosities while lubricating oils or heavy furnace oils, by comparison, have relatively high viscosities. Proper design of fuel-handling systems requires a knowledge of the product's viscosity since this is one factor in determining friction losses in piping systems. Conservative design will assume the viscosity to be that of the product at the temperature at which the product will be handled. Consideration will also be given to possible future requirements for handling a more viscous product in the system. The viscosity of a liquid is expressed in terms of absolute and kinematic viscosity. The definition of each term is as follows:

a. Absolute. The absolute viscosity of a liquid is a measure of its resistance to internal deformation or shear, or the readiness with which a fluid flows when acted upon by an external shearing force. Inasmuch as a variety of units are used to express absolute viscosity, it is extremely important that the value of each be understood. Among such units are poundal seconds per square foot, pound seconds per square foot, pounds per foot second, or slugs per foot second. These are English terms and for the purpose of avoiding confusion are not used in any formulas given herein. Instead, such formulas have been modified by means of a coefficient sc that absolute viscosity, as expressed in units of poise, may be used. The poise has the dimensions of dyne seconds per square centimeter, or grams per centimeter second. A poise is equal to 100 centipoise, the latter being the unit of measure most commonly used. Figure 4 at the end of this section shows equivalents for the most commonly used terms for expressing absolute viscosity.

b. Kinematic. Kinematic viscosity is the ratio of the absolute viscosity to the density of a liquid. When the absolute viscosity is expressed in centipoise, the kinematic viscosity is expressed in centistokes, and the kinematic viscosity becomes the ratio of poise to the density of the liquid expressed in terms of grams per cubic centimeter. A unit of kinematic viscosity is called a stoke. Thus, kinematic viscosity in centistokes is the equivalent of:

$$\frac{\text{absolute viscosity in centipoise}}{\text{density in grams per cubic centimeter}}$$

Since the measurement of absolute viscosity requires elaborate equipment and considerable experimental skill, it is much simpler to measure kinematic viscosity of a liquid by means of a rather simple instrument developed for this purpose. The instrument adopted as standard in this country is the Saybolt Universal viscometer, which measures the time required for 60 cubic centimeters of the liquid to run through the tube of the instrument. For very viscous liquids the Saybolt Furol instrument is used. Other viscosities, somewhat similar to the Saybolt, are the Redwood, the Redwood Admiralty, Engler, and Barbey, but these are not usually used in this country. The viscosities of light petroleum products such as gasolines and jet aircraft engine fuels are given in centistokes, while lubricating and heating oil are given in Saybolt Universal Seconds (S.S.U.). Figures Nos. 5 and 6 at the end of this section show the equivalents of kinematic viscosity, and the kinematic viscosities of several fuels at various temperatures, respectively. Following Figure No. 7 shows the relation between kinematic, S.S.U., and the less commonly used viscosities.

2-6. SUSCEPTIBILITY TO CONTAMINATION. The products to be handled by facilities considered herein are each processed and refined to produce the most satisfactory and economical performance in the type of engine for which it is specified. The introduction of any form of contaminant will lower the quality of the product and seriously impair its efficiency as a fuel, or make the product entirely unsuitable as such. The use of contaminated products can be the cause of serious damage to the engine, and in many cases result in complete engine failure. This is of critical importance in the case of combat vehicles and, to a substantially greater degree, aircraft where the loss of life or vital equipment is involved. Contamination of aircraft- and vehicular engine fuels will be

rought about by intermixing of products, the introduction of
'oreign matter such as water or solids, or by chemical reaction
f the fuel with some component of the fuel handling system.

a. Intermixing of Products. A very small amount of jet-
ngine fuel or diesel oil will contaminate a high antiknock
asoline to such an extent that this quality is reduced
ufficiently to affect its ability to resist knocking and
onsequent loss of power. This condition would be disastrous
o a fully loaded aircraft on takeoff. Gasoline-burning engines
f automotive vehicles use gasolines manufactured to lower anti-
nock specifications than combat aircraft and also contain
ight hydrocarbons, which tend to vaporize readily and which,
hile contributing to the easy starting of cold engines,
ncrease the possibilities of vapor locking in aircraft fuel
ystems at high altitudes or in hot climates. Trainer and
dministrative aircraft use higher antiknock gasoline than
utomotive vehicles, and fighter and bomber aircraft require
ven higher antiknock-value gasolines. An appreciable
ntermixing of these gasolines will reduce the quality of
he mixture to that of the lower and less costly grade. Jet-
ircraft engines can be adjusted to operate to a certain
egree of efficiency with a wide variety of fuels. For
xample, commercial airlines make extensive use of an aviation-
pecification kerosene, and some military jet engines have
een, from necessity, operated with high antiknock-value
asoline. The Navy has used grade JP-5 fuel, and a blend of
this product with aviation gasoline. In this connection, it
should be noted that, while operation of a jet engine with
gasoline containing tetraethyl lead for short durations does
not seriously impair the life of the engine, the continued
use of this fuel will increase the frequency of need for
engine overhaul and cut down on engine life because of the
deposit of lead on the engine parts. Although a moderate
proportion of gasoline containing tetraethyl lead will not
seriously contaminate grade JP-4 fuel, increasing large
additions of any gasoline will tend to cause this fuel to
take on the heretofore described undesirable high-volatility
characteristics of grade JP-3. It follows that additions of
kerosene-type fuels or distillates tend to increase the poor
starting qualities objected to in grade JP-1. Jet-aircraft
engines in current design are being test operated on still
other fuels, each made to accomplish a specific result under
conditions of speed, altitude, and temperature. The only safe

conclusion that can be reached is that these fuels must not be mixed with one another, or with other liquid fuels. Factors that tend to aggravate knocking in a spark-ignition engine tend to suppress it in a combustion-ignition engine. The ignition quality of a fuel for a combustion-ignition engine, where sudden combustion of the atomized fuel at a critical stage of compression is needed, is indicated by the time lag between the beginning of fuel injection and the sudden increase in pressure caused by the combustion. This quality is determined by comparison of the ignition qualities of a fuel to those for blends of specified fuels of known cetane value in a specified diesel engine under specified conditions of operation. The cetane scale extends from 0 to 100, and fuels having high cetane numbers will burn more smoothly and start cold engines more readily than fuels having low cetane numbers. Small quantities of gasoline in diesel fuel will contaminate the diesel fuel sufficiently to materially affect the performance of the engine. This fact requires precautions against intermixing of aviation gasolines with diesel-engine oils. As stated above, methyl alcohol is semisoluble in gasoline and other hydrocarbon liquids, and intermixing of the products will result in lowering the antifreeze properties of the alcohol.

b. Water Tolerance. Liquid hydrocarbon fuels are all lighter in weight than water and will separate sharply from entrained water in stationary containers, after sufficient time has elapsed for the water to settle to the bottom. The time required for this settlement to take place will be substantially increased when the fuel and entrained water have been violently mixed, such as by the passage together through a centrifugal pump. The settlement time will be greater as the weight of the fuel more nearly approximates that of water. This is true for jet-engine fuel, which weighs more than gasoline. The solubility of water in liquid hydrocarbons is quite low and decreases with the temperature. Thus, lowering of the fuel's temperature tends to release small amounts of dissolved water. This tendency of the fuel to release dissolved water during lowering temperatures, until the dissolved water is released in the form of ice crystals at extremely low temperatures, has complicated the handling of these products and caused clogging of line strainers,

filters, and filter/separators when such temperatures are encountered. At temperatures below that at which water will freeze, the passage of fuel to aircraft engines will be blocked by ice in the aircraft's fuel-system strainers. For this reason, it is of critical importance to prevent delivery of fuel containing free water to any aircraft. The introduction of any water into containers for the storage of the straight alcohol will reduce the strength of the alcohol and require corrective adjustments to an alcohol and water blend made up on the assumption that undiluted alcohol was being used.

c. Contamination by Foreign Solids. Solid contaminants such as foreign debris, or normal rust and scale particles from steel tanks and piping systems must be prevented from entering the fuel systems of all types of aircraft, as they will cause clogging of the filters on the engine-fuel feed lines and scoring of close precision-fit moving engine parts if passed through the filter.

d. Contamination from Contact with Components of the Fuel-Handling System. Two of the minor components that may be present in aircraft engine fuels are mercaptans and naphthenic acids. Mercaptans are sulphur compounds often found in petroleum streams but limited by current specifications for jet-engine fuel to a maximum concentration of 0.005 percent. It has been noted that mercaptan sulphur will cause corrosion of cadmium, and that the corrosion becomes greater if water is present. Naphthenic acids are organic acids and are likely to be present in greater quantities in high-boiling products such as jet-engine fuels. Their concentration is not limited in present aviation fuel specifications. Zinc is rapidly attacked by naphthenic acids to produce zinc naphthenates, which are soluble in the fuel. Minute amounts of zinc have been found to be highly detrimental to hot parts of both jet and reciprocating engines, and, for this reason, the use of zinc-containing coatings and galvanized materials will not be permitted in storage tanks or other parts of the fuel-handling system that come in contact with the fuel. Whenever possible, the selection of materials for components of the aircraft engine-fuel-handling systems will avoid the use of cadmium-plated steel, copper, and brass, as these metals are more susceptible to corrosion from the fuel than are steel, black iron, and aluminum. Methyl alcohol is listed as

corrosive to aluminum in Chemical Safety Data Sheet No. SD-22 published by the Manufacturing Chemists Association. This organization considers alcohol to be inert to black iron, carbon steel, and nonferrous materials other than aluminum.

2-7. HARMFUL EFFECTS ON MATERIALS. One characteristic of all gasolines, and to some degree their vapors, is their ability to dissolve petroleum oils and portions of grease. This must be taken into consideration in the specifications for lubricants for pump shafts, and valves for gasoline service. Some pipe-thread joint pastes that are immune to solution in lower grades of gasoline are partially dissolved by the high-antiknock-value aviation gasolines containing aromatic hydrocarbons, and form a tacky mass, that will plug strainers and filters. High-antiknock-value aromatic aviation gasolines have the ability to soften and deteriorate natural rubber and some types of synthetic rubbers, and these cannot be used in hoses, gaskets, packings, or other seals that come in contact with the gasoline. Jet-aircraft engine fuels contain sufficient gasoline and aromatics to be capable of these same actions. In addition, the characteristics of a penetrating oil develop in jet-engine fuels and cause possibilities for leaks to occur where gasoline will not get through. These characteristics also cause these fuels to loosen rust and scale that have adhered to pipe and tank interiors of systems previously used for aviation gasoline. The action of diesel oil on lubricants, rubber, and pump seals is not as rapid as that of gasoline, but the action exists, and materials capable of resisting this action must be used on all parts of the system in contact with these products. Methyl alcohol, and to some degree its vapors, will dissolve shellac, gums, dyes, and certain oils, but is not harmful to rubber, asbestos, cork, and most valve packing. These products will dissolve or leach the asphalt in a pavement if allowed to drip or to spill without prompt removal by washing with a hose stream, or by absorbing it with sand, earth or other inert material. Because of its lower rate of evaporation, jet-engine fuel is particularly harmful to such pavement. For this reason, rigid concrete pavement will be provided for the parking of truck tanks at unloading positions or at truck-fill stands. All pavement-joint sealers will be a jet-fuel-resistant type.

-8. HARMFUL EFFECTS ON PERSONNEL. The concentration of asoline vapors that can be tolerated by a man is far below nat required to produce combustible or explosive mixtures ith air, one tenth of this amount being harmful if inhaled or more than a short time. Moderate amounts will cause izziness, nausea, and headache; while large amounts act s an anesthetic and cause unconsciousness. All gasolines nd hydrocarbon fuels must be regarded as toxic. This is qually true for methyl alcohol. Lead poisoning from the nhalation of vapors of gasoline treated with tetraethyl ead, while not to be feared from inhalation of vapors given ff from open containers, will occur if these vapors are nhaled over a long period in an inadequately ventilated nclosure. Jet-engine fuels contain sufficient gasoline to ause this fuel to be regarded as toxic, but do not contain ny tetraethyl lead. Gasoline will cause severe burns if llowed to remain in contact with the skin, particularly nen the contact is maintained under soaked clothing or loves. Lead in gasoline is not absorbed through the skin o any important extent. However, methyl alcohol may be bsorbed through the skin in sufficient quantities to cause ne general effects of inhalation as a vapor. Methyl alcohol lso causes irritation of the skin by removing natural skin ils, causing cracking of the skin. This increases the ossibilities of infection. The danger to personnel from nhalation of the product's vapors or external contact with ne liquid is another reason why design of facilities for andling these products must avoid deficiencies, that ncrease the possibilities of spillage or the accumulation f vapors from these products in confined areas.

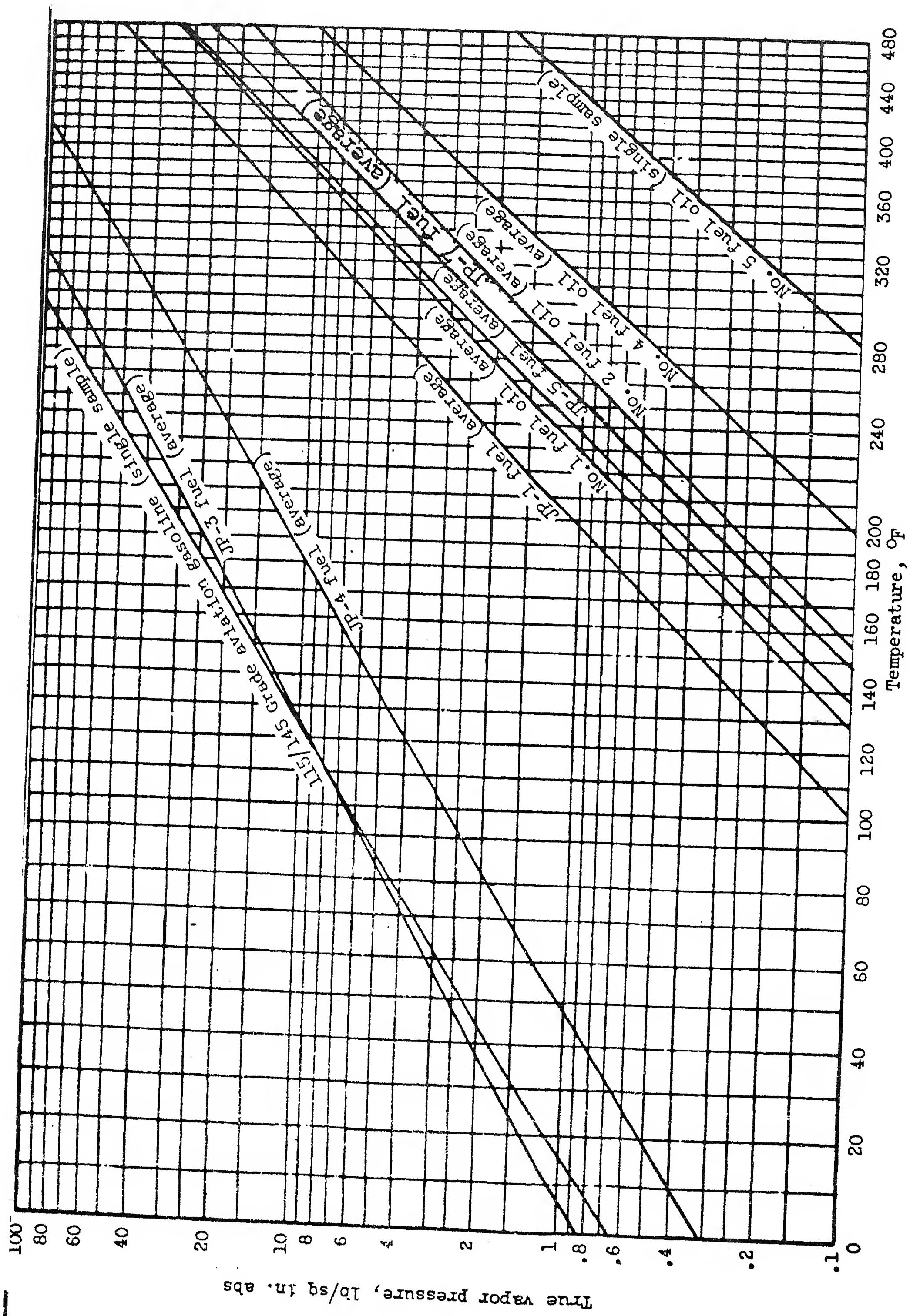

FIGURE 1
VARIATION OF VAPOR PRESSURE WITH TEMPERATURE FOR DIFFERENT FUELS

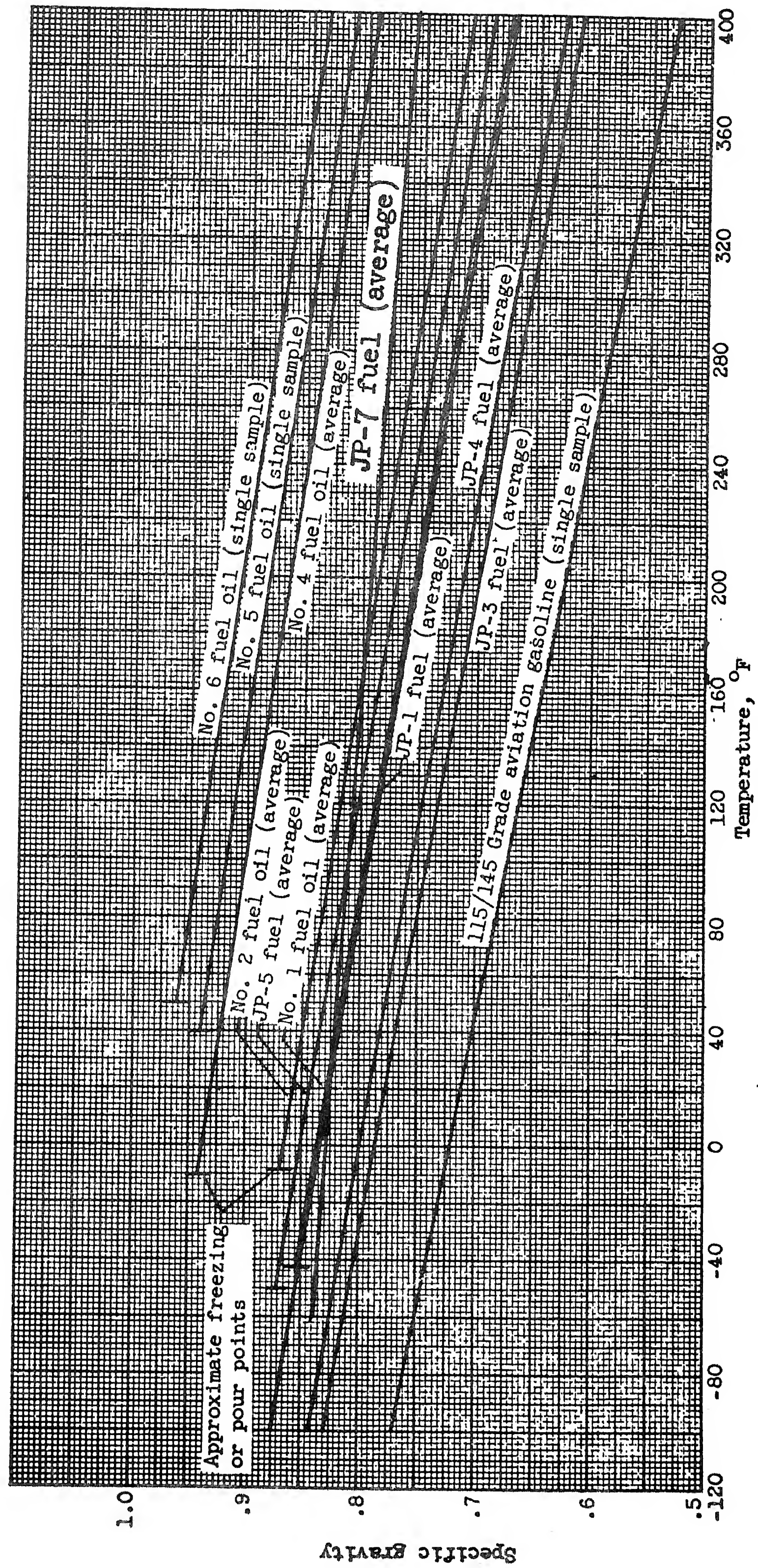

FIGURE 2

VARIATION OF SPECIFIC GRAVITY WITH TEMPERATURE

FIGURE 3
A.P.I. GRAVITY — SPECIFIC GRAVITY RELATION

Deg. API	Spec. Gr.	Pounds per Gal.	Deg. API	Spec. Gr.	Pounds per Gal.	Deg. API	Spec. Gr.	Pounds per Gal.	Deg. API	Spec. Gr.	Pounds per Gal.
0	1.076	8.96	40	.825	6.87	80	.669	5.568	120	.563	4.68
1	1.068	8.90	41	.82	6.83	81	.666	5.54	121	.56	4.66
2	1.06	8.83	42	.816	6.79	82	.663	5.52	122	.558	4.64
3	1.052	8.76	43	.811	6.75	83	.659	5.49	123	.556	4.63
4	1.043	8.70	44	.806	6.71	84	.656	5.46	124	.554	4.61
5	1.037	8.62	45	.802	6.67	85	.654	5.44	125	.552	4.59
6	1.028	8.55	46	.797	6.64	86	.65	5.42	126	.55	4.575
7	1.02	8.50	47	.793	6.60	87	.647	5.39	127	.547	4.56
8	1.014	8.45	48	.788	6.56	88	.645	5.36	128	.545	4.54
9	1.007	8.37	49	.784	6.53	89	.642	5.34	129	.543	4.52
10	1.00	8.33	50	.779	6.49	90	.639	5.32	130	.541	4.51
11	.993	8.27	51	.775	6.46	91	.636	5.29	131	.539	4.49
12	.986	8.21	52	.771	6.42	92	.633	5.27	132	.537	4.47
13	.979	8.16	53	.767	6.39	93	.63	5.25	133	.535	4.45
14	.973	8.10	54	.763	6.35	94	.628	5.22	134	.533	4.43
15	.966	8.04	55	.759	6.32	95	.625	5.19	135	.531	4.42
16	.959	7.99	56	.755	6.28	96	.622	5.18	136	.529	4.40
17	.953	7.94	57	.75	6.25	97	.619	5.15	137	.527	4.38
18	.946	7.88	58	.747	6.22	98	.617	5.13	138	.525	4.37
19	.94	7.83	59	.743	6.18	99	.614	5.11	139	.523	4.35
20	.934	7.78	60	.739	6.151	100	.611	5.086	140	.521	4.34
21	.928	7.73	61	.735	6.12	101	.608	5.06	141	.519	4.32
22	.922	7.68	62	.731	6.09	102	.606	5.045	142	.517	4.30
23	.916	7.63	63	.728	6.06	103	.604	5.03	143	.515	4.28
24	.910	7.58	64	.724	6.03	104	.602	5.015	144	.514	4.27
25	.904	7.53	65	.72	5.99	105	.598	4.98	145	.512	4.26
26	.898	7.48	66	.716	5.96	106	.596	4.96	146	.51	4.245
27	.893	7.43	67	.713	5.93	107	.594	4.94	147	.508	4.23
28	.887	7.39	68	.709	5.90	108	.591	4.92	148	.506	4.21
29	.882	7.34	69	.706	5.87	109	.589	4.90	149	.504	4.19
30	.876	7.30	70	.702	5.845	110	.586	4.88	150	.502	4.18
31	.871	7.25	71	.699	5.82	111	.584	4.855	151	.501	4.17
32	.865	7.21	72	.695	5.79	112	.581	4.845	152	.499	4.16
33	.860	7.16	73	.692	5.76	113	.579	4.82	153	.497	4.14
34	.855	7.12	74	.689	5.73	114	.576	4.80	154	.496	4.13
35	.85	7.08	75	.685	5.70	115	.574	4.78	155	.494	4.11
36	.845	7.03	76	.682	5.67	116	.572	4.76	156	.493	4.10
37	.840	6.99	77	.679	5.65	117	.570	4.745	157	.49	4.09
38	.835	6.95	78	.675	5.62	118	.567	4.72	158	.489	4.07
39	.83	6.91	79	.672	5.59	119	.565	4.70	159	.487	4.06

FIGURE 4
EQUIVALENTS OF ABSOLUTE VISCOSITY

Absolute or Dynamic Viscosity		Centipoise (μ)	Poise $\frac{\text{Gram}}{\text{Cm Sec}}$ $\frac{\text{Dyne Sec}}{\text{Cm}^2}$ ($100\ \mu$)	$\frac{\text{Slugs}}{\text{Ft Sec}}$ $\frac{\text{*Pound}_f\ \text{Sec}}{\text{Ft}^2}$ (μ'_e)	$\frac{\text{†Pound}_m}{\text{Ft Sec}}$ $\frac{\text{Poundal Sec}}{\text{Ft}^2}$ (μ_e)
ntipoise	(μ)	1	0.01	2.09 (10^{-5})	6.72 (10^{-4})
Poise $\frac{\text{Gram}}{\text{m Sec}}$ $\frac{\text{yne Sec}}{\text{Cm}^2}$	($100\ \mu$)	100	1	2.09 (10^{-3})	0.0672
$\frac{\text{Slugs}}{\text{Ft Sec}}$ $\frac{\text{ound}_f\ \text{Sec}}{\text{Ft}^2}$	(μ'_e)	47 900	479	1	g or 32.2
$\frac{\text{Pound}_m}{\text{Ft Sec}}$ $\frac{\text{undal Sec}}{\text{Ft}^2}$	(μ_e)	1487	14.87	$\frac{1}{g}$ or .0311	1

*Pound_f = Pound of Force †Pound_m = Pound of Mass

T(ɔnvert absolute or dynamic viscosity from one se ' units to another, locate the given set of units in : left hand column and multiply the numerical va by the factor shown horizontally to the right ur · the set of units desired.

As an example, suppose a given absolute viscosity of 2 poise is to be converted to slugs/foot second. By referring to the table, we find the conversion factor to be 2.09 (10^{-3}). Then, 2 (poise) times 2.09 (10^{-3}) = 4.18 (10^{-3}) = 0.00418 slugs/foot second.

FIGURE 5
EQUIVALENTS OF KINEMATIC VISCOSITY

Kinematic Viscosity		Centistokes (ν)	Stokes $\frac{\text{Cm}^2}{\text{Sec}}$ ($100\ \nu$)	$\frac{\text{Ft}^2}{\text{Sec}}$ (ν')
Centistokes	(ν)	1	0.01	1.076 (10^{-5})
Stokes $\frac{\text{Cm}^2}{\text{Sec}}$	($100\ \nu$)	100	1	1.076 (10^{-3})
$\frac{\text{Ft}^2}{\text{Sec}}$	(ν')	92 900	929	1

T onvert kinematic viscosity from one set of units t nother, locate the given set of units in the left h d column and multiply the numerical value by t factor shown horizontally to the right, under t set of units desired.

As an example, suppose a given kinematic viscosity of 0.5 square foot second is to be converted to centistokes. By referring to the table, we find the conversion factor to be 92,900. Then, 0.5 (sq ft sec) times 92,900 = 46,450 centistokes.

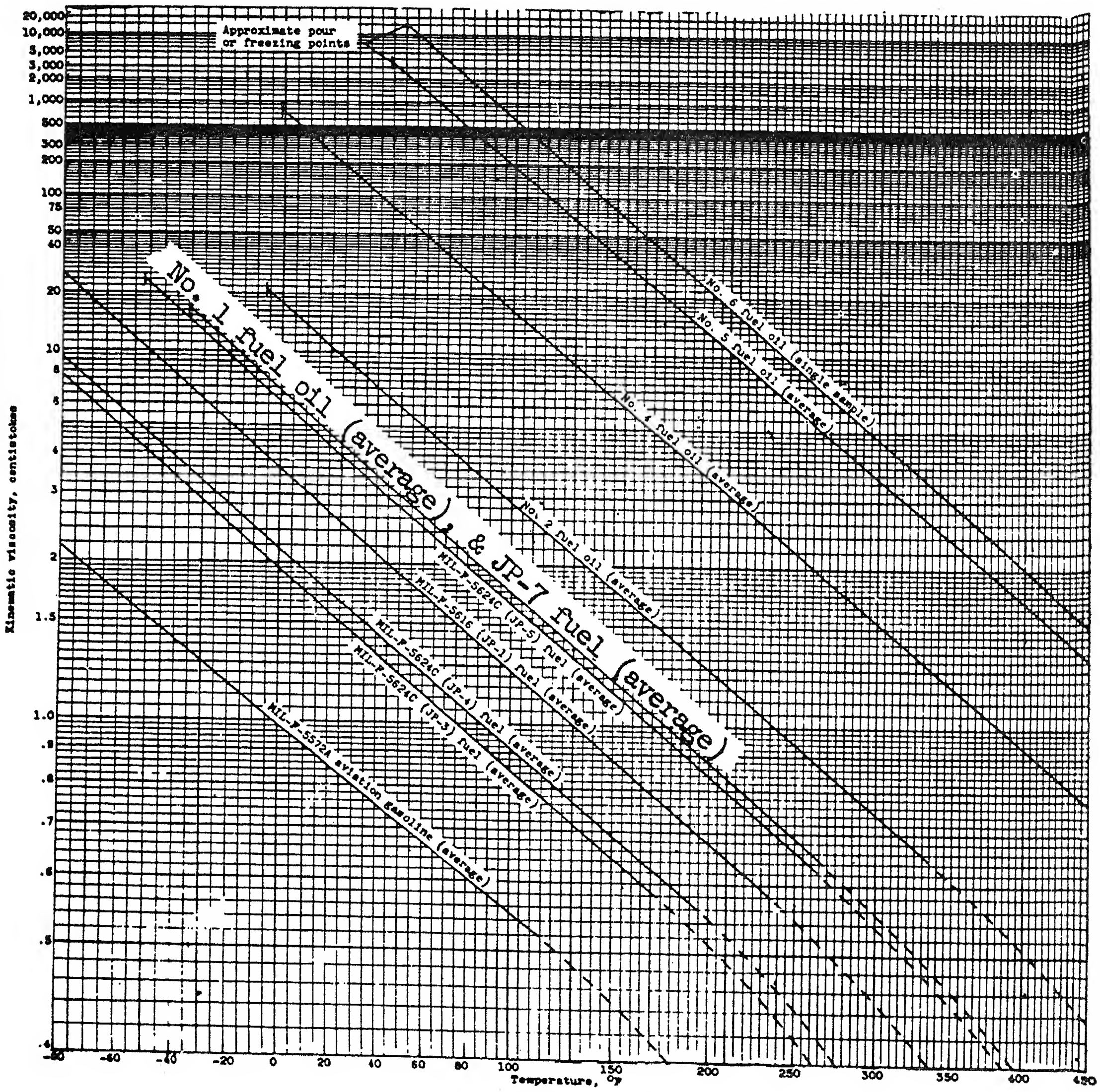

FIGURE 6

VISCOSITY – TEMPERATURE RELATION FOR SEVERAL FUELS

FIGURE 7

VISCOSITY CONVERSION TABLE

Kinematic Viscosity Centistokes = K	Seconds Saybolt Universal	Seconds Saybolt Furol	Seconds Redwood	Seconds Redwood Admiralty	Degrees Engler	Degrees Barbey
1.00	31	....	29.	....	1.00	6200
2.56	35	....	32.1	....	1.16	2420
4.30	40	....	36.2	5.10	1.31	1440
5.90	45	....	40.3	5.52	1.46	1050
7.40	50	....	44.3	5.83	1.58	838
8.83	55	....	48.5	6.35	1.73	702
10.20	60	....	52.3	6.77	1.88	618
11.53	65	....	56.7	7.17	2.03	538
12.83	70	12.95	60.9	7.60	2.17	483
14.10	75	13.33	65.0	8.00	2.31	440
15.35	80	13.70	69.2	8.44	2.45	404
16.58	85	14.10	73.3	8.86	2.59	374
17.80	90	14.44	77.6	9.30	2.73	348
19.00	95	14.85	81.5	9.70	2.88	326
20.20	100	15.24	85.6	10.12	3.02	307
31.80	150	19.3	128	14.48	4.48	195
43.10	200	23.5	170	18.90	5.92	144
54.30	250	28.0	212	23.45	7.35	114
65.40	300	32.5	254	28.0	8.79	95
76.50	350	35.1	296	32.5	10.25	81
87.60	400	41.9	338	37.1	11.70	70.8
98.60	450	46.8	381	41.7	13.15	62.9
110.	500	51.6	423	46.2	14.60	56.4
121.	550	56.6	465	50.8	16.05	51.3
132.	600	61.4	508	55.4	17.50	47.0
143	650	66.2	550	60.1	19.00	43.4
154	700	71.1	592	64.6	20.45	40.3
165	750	76.0	635	69.2	21.90	37.6
176	800	81.0	677	73.8	23.35	35.2
187	850	86.0	719	78.4	24.80	33.2
198	900	91.0	762	83.0	26.30	31.3
209	950	95.8	804	87.6	27.70	29.7
220	1000	100.7	846	92.2	29.20	28.2
330	1500	150	1270	138.2	43.80	18.7
440	2000	200	1690	184.2	58.40	14.1
550	2500	250	2120	230	73.00	11.3
660	3000	300	2540	276	87.60	9.4
770	3500	350	2960	322	100.20	8.05
880	4000	400	3380	368	117.00	7.05
990	4500	450	3810	414	131.50	6.26
1100	5000	500	4230	461	146.00	5.64
1210	5500	550	4650	507	160.50	5.13
1320	6000	600	5080	553	175.00	4.70
1430	6500	650	5500	559	190.00	4.34
1540	7000	700	5920	645	204.50	4.03
1650	7500	750	6350	691	219.00	3.76
1760	8000	800	6770	737	233.50	3.52
1870	8500	850	7190	783	248.00	3.32
1980	9000	900	7620	829	263.00	3.13
2090	9500	950	8040	875	277.00	2.97
2200	10000	1000	8460	921	292.00	2.82

SECTION 3. GENERAL CONSIDERATIONS

3-1. UNIFORMITY OF DESIGN. In order to maintain a uniformity and tandardization of design, the instructions contained in thi and other sections of this manual will be strictly adhered to enever practicable. When standard drawings and technical spe fications have been issued by the Office of the Chief of Eng eers for a particular type of installation, the standard dra ngs and technical specifications will be used to supplemen this manual. Instructions from the Office of the Chief of gineers of a more recent date than this manual or related sta ard drawings and technical specifications will take preced ce over similar instructions contained in or implied by the atter. Deviations from established criteria and standards may e necessary in certain special cases because of local condit ns and requirements. In all such cases, the revised design * wil be presented to HQDA(DAEN-MCE-U) or HQ USAF/PREES for pproval. In the absence of specific instructions for spe al conditions, problems, or details, established commercia practices will be followed insofar as these practices are ompatible with military requirements.

3-2 COORDINATION WITH DESIGN OF OTHER FACILITIES. Designs for ngine-fuel-handling facilities will be coordinated with des ns of docks, railroads, roadways, airfield pavement, uti ties, and other related installations. Whenever design and onstruction schedules permit, those portions of the fuel-han ing-system pipelines or electrical ducts that are to ext d under new railroads, roadways, or airfield pavement will be ogramed for installation in advance of, or concurrent wit the construction of the latter facility. Extension of ele rical-power supply, water service, and other utilities and onstruction of railroad spur tracks and roadways to, and wit n, the fuel-handling facility will be included in projec for such facilities whenever practicable.

3-3 FIRE AND EXPLOSION PROTECTION. Engine-fuel-handling sys ms designed in accordance with criteria contained in this man l will conform to all current instructions from the Office of e Chief of Engineers pertaining to safety and the preventic of fire and explosion.

a. <u>Fire Prevention</u>. Inasmuch as the presence of vapor from the liquid, air, and a source of ignition are all re- quired to start a fire, it follows that designs that elimi- nate or materially reduce the possibility for the existence of any one of these three requirements will contribute sub- stantially to the prevention of fire and explosion. This condition can be accomplished to a considerable degree by observance of criteria contained in following sections of this manual concerning clearances; use of tanks for bulk storage of aircraft-engine fuels of a design that prevents the accumulation of air and fuel-vapor mixtures between the liquid surface and the tank roof; or, when this design is not feasible, careful attention to the requirements for venting; provision of adequate dikes for all aboveground installed tanks; forced air ventilation of pumprooms and pressurization of electrical control rooms; use of explo- sion-proof electrical wiring and apparatus; and the design of piping systems. Portable CO_2 equipment will be pro- vided by the using agency for fire protection in inclosed areas such as pits, pumphouses, or filter/separator build- ings. Installed CO_2 systems will not be provided for the above buildings.

b. <u>Fire Protection for Army Installations</u>. Aircraft and vehicular fuel bulk storage, area reserve, and other similar flammable liquid storage facilities that are remotely located with relation to public or base water systems will generally be dependent on recognized safe design, siting, and operational practices for protection against fire and explosion hazards. In-built fire and explosion protection features include use of floating-roof-type tanks, conformance to recognized industry practices with respect to clearances between tanks, diking of tank areas, venting, and elimination of possible ignition sources. Development or extension of water hydrant systems suitable for fire-protection requirements or the provision of other types of complete or partially installed or fixed sys- tems or maintenance of mobile fire departments will not generally be authorized. Where such a facility is of a critical nature or is of a high strategic or monetary value and there are de- ficiencies of a sufficiently severe nature as to justify some degree of fire protection, appropriate recommendations will be furnished with necessary supporting information to
* HQDA (DAEN-MCE-U) WASH DC 20314, for consideration. Facili-

ies that are situated on base within economic distance of ire-hydrant water systems may be provided with hydrants and upporting supply mains for use by existing or available fire epartments. Design of hydrant systems for these situations ill be based on affording protection to nearby storage tanks, tructures or other facilities. A fire flow of 1,000 g.p.m. t 10 p.s.i. will normally not be exceeded.

c. Fire Protection for Air Force Installations. Fire hy-rants with adequate water supply for protection of on-base perating and bulk fuel storage facilities will be provided. nasmuch as all aboveground bulk fuel tanks 5,000 bbls. and arger will have floating roofs, no fixed foam system will be rovided at on-base installations. At off-base area-reserve ulk storage installations, water supply for fire protection ill be obtained from local municipal facilities when available. hen such facilities are inadequate or unavailable, water upply will be obtained from lakes, rivers, harbors, specially onstructed reservoirs, or wells drilled for this purpose. n the event municipal fire-fighting equipment is not avail-ble to an off-base bulk storage facility, consideration may e given to an installed foam system. The design of the foam ystem will conform to that shown on Drawing No. 78-24-23, 'Standard Area Reserve Tank Farm". However, the foam system ill be installed only on specific authorization by HQ USAF AFOCE-K), Wash DC 20330.

-4. PRECAUTIONS AGAINST CONTAMINATION OF PRODUCTS. Pre-autions to prevent intermixing of products, or delivery of 'uels diluted by water or containing solid contaminants, will nclude the following:

a. Segregation of Products. Separate receiving, storing, nd dispensing facilities will be provided for each type and rade of product. No interconnection between the piping ystem on the receiving or dispensing side of storage will e permitted. Segregation of systems at manifold points rovided for realinement of tankage will be accomplished by eans of removable flanged pipe sections or fittings, and he installation of blind flanges on either side of the emoved pipe section or fitting. Where space limitations pre-lude the use of removable pipe sections or fittings, the use f combination line blanks and spectacle plates will be permitted. The only exceptions will be where the installation of multiproduct

cross-country pipelines are specifically authorized for economic reasons by the Office of the Chief of Engineers. In such cases, segregation of products will be maintained at the tank farm, and separation of products will be accomplished at the connections to the multiproduct pipeline by the installation of line blinds with manually-operated block valves on either side, or by means of double block and bleed valves. Special provisions to separate cargoes in the multiproduct pipeline by means of batching pigs or strictly supervised control of interfacial mixtures will be incorporated at all points where products are delivered to, or received from, the line. Separation of cargoes by means of water slugs will not be permitted.

b. Water Contamination in Fuel, Removal.

(1) In underground tanks. Removal of water collected at the bottom of underground tanks will be accomplished by using a portable motor-driven pump with the suction hose extended to the bottom of the tank through the gage and cleanout pipe, or by a portable hand pump connected to a suction pipe extended to the bottom of the tank, or by a vertical centrifugal-type sump pump mounted over the tank. The suction capabilities of each type of pump will determine which to use

(2) In aboveground tanks. All aboveground tanks will be equipped with a center sump having a valved drain pipe to the exterior of the tank.

(3) Preventing water from entering fuel delivery system. The suction for the fuel delivery pumps will terminate not less than 6 inches above the botto of underground tanks. Filter/separators suitable for removing water and solids will be installed at dispensing points for all refined products, and in addition for jet fuels will be installed at all transfer areas. For underground fuel storage tanks in aviation fuel service, a low-level float-operated switch will be installed to interrupt the power supply to all delivery pumping units when the liquid level in the tank falls between 8 and 10 inches from the bottom of the tank.

c. Solids Contamination in Fuel, Removal. Removal of solid contaminating matter from all fuels for automotive vehicles and aircraft use will be accomplished as follows. Deliveries to bulk storage tanks via pipeline, and deliveries to barges, tankers, and military supply ships, will pass through a solids separator of either the centrifugal type or self-cleaning strainer type. Line strainers will be provided in the piping system for delivery of fuel to bulk storage tanks via tank car or tank truck, upstream of filter/separator, meters, and pumps, except vertical pumps which shall be provided with a coarse grating or heavy wire mesh. Filter/separators will be provided when dispensing to tank car or tank truck fill stands, and t the fill point to operating storage tanks for hydrant fueling systems.

d. Pipeline Identification. All pipelines will be color coded and identified as to product in accordance with current Military Standards, and all refueling hydrant outlet couplers will be fitted with different lugging for each kind and grade of fuel dispensed.

3-5. PRODUCT STORAGE TANKS. Bulk storage of aviation fuels, and automotive fuels, including diesel, at installations within the continental limits of the United States will be in aboveground tanks unless underground tanks are specifically authorized. Storage of methyl alcohol and water-alcohol blend, operating storage of aircraft-engine fuels at Air Force bases, Air National Guard, and Army installations, and storage of automotive fuels will normally be in underground horizontal tanks. Storage of these fuels at overseas installations, and hardening requirements for blast protection, will be determined by the using service in accordance with DOD 4270.1-M, AR 415-22, or AFM 88-15.

Area reserve storage depots will be either aboveground or underground as determined by the Department of Defense.

a. Aboveground Tanks. Aboveground tanks for storage of aircraft-engine fuels in capacities of 5,000 barrels or greater will have a floating pan with cone roof. Details of design for such tanks will be as shown on Standard Drawing No. 78-24-27. Aboveground tanks for storage of aviation fuels in capacities less than 5,000 barrels, and for bulk storage of automotive fuels including diesel will have stationary cone roofs. Cone-roof tanks for storage of automotive fuels will be of dimensions and details of design as shown on applicable sheets of Drawing No. 78-24-16, -17, or -18. Details of design for cone-roof tanks of other capacities will conform to applicable portions of API Standard "Specifications for Welded Storage Tanks," published by American Petroleum Institute, Division of Production, 300 Corrigan Tower Building, Dallas, Texas 75301. Hardening of existing aboveground tanks, where authorized for protection to resist the effects of atomic blast, will be as described in paragraph 5-12. The exterior of aboveground tanks will be painted as required by TM 5-618/AFM 85-3.

b. Underground Hardened Bulk-Storage Tanks and Operating Storage Tanks. Underground hardened tanks for bulk storage of aircraft or vehicular-engine fuels will be cylindrical, vertical tanks conforming to Standard Drawing No. 78-24-04,-05, -06, -07, or-08, depending on the capacity required. Underground tanks for storage of methyl alcohol and water-alcohol blends will be 25,000-gallon-capacity nonpressure tanks suitable for horizontal installation. Such tanks will conform to Standard Drawing No. AW 78-25-01. Underground operating storage tanks for multiple-outlet hydrant-type aircraft refueling systems will be 50,000-gallon-capacity, cylindrical, nonpressure tanks suitable for horizontal installation.

Details of design will be as shown on applicable sheets of Standard Drawing No. 78-24-01, or Drawing 78-24-26, for conventional systems, or 78-24-21 for hardened systems. Underground operating storage tanks for single-outlet hydrant-type aircraft refueling systems will be cylindrical nonpressure tanks suitable for horizontal installation, 50,000-gallon capacity. Tanks for hydraulic-displacement-type systems will be 25,000-gallon capacity, cylindrical, pressure tanks suitable for horizontal underground installation. These tanks will be designed to withstand a test pressure of not less than 90 p.s.i. All openings will be in the top of the tank. These openings will include a 6-inch water-fill stem extending from 3 inches above the bottom to approximately 6 inches above the top where it will be threaded for connection of the water-supply line; a 4-inch flanged nozzle for mounting of a float-operated product-fill control valve; a 15-3/4-inch-I.D. flanged nozzle for mounting of a float-operated direct-reading liquid-level gage; a 4-inch cleanout pipe extending from 3 inches above the bottom to the outside of the tank where it will be fitted with a gate valve and protective cap; and a 2-inch coupling for the installation of a stick-gage pipe on the outside of the tank. The stick-gage pipe will be fitted with a swing check valve installed to prevent flow from the tank, and a protective cap. Operating storage tanks for Army Aviation fueling systems will be sized as authorized. Typical tank designs are shown on Standard Drawing No. 78-24-20. Operating storage tanks for Air National Guard fueling systems will be 25,000-gallon-capacity, cylindrical, nonpressure tanks suitable for horizontal installation.

(1) Exterior protective coating for underground tanks. With the exception of bottom plates of vertically installed tanks, the exterior surfaces of all underground tanks will be primed and coated with coal-tar primer and enamel. The exterior bottom plates will not be coated.

(2) Anchorage for underground tanks. All underground tanks will be installed on, and tied down to, concrete mats. The bottom plates of vertical tanks will be welded to inserts set into the concrete. Straps will be passed over horizontally installed tanks and welded to inserts set into the slab. Bolting will not be permitted. The weight of the concrete mat and the strength of the tiedown attachment will be sufficient to prevent displacement of an empty tank.

(3) Backfill for underground tanks. Backfill for all underground tanks will include placing a 6-inch-thick course of inert sand or fine gravel against all exposed exterior surfaces. If economy prohibits

se of clean inert sand or gravel, insulating fiberboard or urethane will be placed against the tank before backfilling.

c. Protective Coating for Interior of Storage Tanks. Tanks will be coated with an epoxy or urethane coating system as described in Department of Defense Manual AD 666969, "Interior Coating Systems for Surfaces in Contact with Petroleum Fuels." Coating requirements are:

(1) Air Force. Tanks to be used for storage of aviation fuel will be coated. The coating will be applied to the interior of horizontal steel tanks and vertical steel tanks. The underside of the steel flat or cone roof and the top and bottom of the floating pan will be included in the coating system.

(2) Army. All horizontal steel tanks to be used for storage of aviation fuels will be coated. As a minimum, all vertical steel tanks storing petroleum products will be coated on the interior bottom plates, and vertical steel plates, to a height of approximately 4 feet. Floating roofs installed ir tanks will be coated on the underside.

d. Storage Tank Accessories. Storage tanks will be provided with fittings and accessories as shown on the applicable standard drawings. Sizes of pressure/vacuum breather vent valves for aboveground tanks and underground tanks over 40,000 gallons used for aircraft or automotive fuel storage will be in accordance with American Petroleum Institute, Bulletin RP 2000, "Guide for Venting Atmospheric and Low-Pressure Storage Tanks." Tanks for diesel and residual fuels will have atmospheric vents, and the vents will be sized similar to the pressure/vacuum breather vent sizes. All venting shall terminate at an elevation of approximately 12 feet above grade or 2 feet above the building roof when the tank is installed under or partly under, or immediately adjacent to a pumphouse or similar structure. Commercial flame arrestors will not be provided in conjunction with breather-valve type or atmospheric type vents. Internal swing lines or fittings will not be permitted that would allow the fuel to enter the delivery system from a point below the withdrawal nozzle.

3-6. PUMPHOUSES AND FILTER/SEPARATOR BUILDINGS. Pumphouses and filter/separator buildings are required for protection of equipment from the elements. Pumphouses consisting of a pumproom and a control room are required for Air Force and Air National Guard installations. Shelters for pumping equipment for Army installations will not be required except in heavy snow areas where shelters are desirable for maintenance of equipment. Filter/separator buildings will be provided at Army aviation installations, and will contain filter/separator equipment only. These structures will conform to the following criteria:

a. Pumprooms and Filter/Separator Buildings. Inclosed-type pumprooms and filter/separator buildings will be provided in all cases where the local design temperature is below plus 20 degrees F., and will be provided regardless of local design temperature where sand and dust storms create difficult maintenance problems. Inclosed pumprooms will also be provided wherever atomic-blast-resistant-type pumphouses are authorized. Open-type shelters will be provided under all other conditions than those excepted above.

b. Control Rooms. Control rooms will be inclosed and isolated from the pumproom. Windows will have fixed sash, and a double-glazed observation window will be provided to observe pumproom operations. Pump controls for Army Aviation will be mounted on a panel at the exterior of the building.

c. Toilet Rooms. Toilet rooms will be provided in transfer pumphouses remotely located from other structures having such facilities. Access to toilet rooms from pumprooms or control rooms will not be permitted except where hardened pumphouses are authorized.

d. Heating Systems. Pumprooms, control rooms, and filter/separator buildings will be heated where the local design temperature is below plus 20 degrees F. Toilet rooms will be heated where the local design temperature is below plus 30 degrees F. Heating systems will be regulated to maintain temperatures of plus 40 degrees F. in pumprooms and filter/separator buildings, and plus 60 degrees F. in control rooms and toilet rooms. Electric heating units will be provided

except where it can be determined that electric heat is not feasible from an economic or operational standpoint Under the latter circumstances, the heating system will be steam or hot-water type with supply from a central plant or supplementary plant constructed a minimum distance of 100 feet from the pumphouse or filter/separator building, or other hazardous locations. Space heating by open flame or open electrical elements will not be permitted.

e. Forced-Air Systems. Forced-air ventilating systems will be provided for all inclosed pumproom and filter/separator buildings. These systems will be designed for six changes of air per hour. Control rooms will be pressurized to maintain a 1/2-inch static pressure. Forced-air systems will conform to applicable requirements of TM 5-810-1/AFM 88-8, Chapter 1.

f. Plumbing. Hydrant-type floor washers of the non-wasting frostproof design will be provided in all pump and filter/separator rooms. Plumbing fixtures for toilet rooms and floor washers will have sanitary features that conform to the requirements of the National Plumbing Code.

g. Floor and Equipment Drains. Floor drains will be provided in structures where filter/separator units are installed. An open-end riser with connection to an underfloor drain system will be provided to receive water discharge from each filter/separator unit. One or more floor drains with connection to the underfloor drain system will be provided. The underfloor drain system will extend from the filter/separator and floor drains to a collection tank installed underground on the exterior of the building. The underfloor-drain-system piping will not be connected to storm drains or sanitary sewers. Traps that would permit possible accumulation of aircraft-engine fuels will not be provided in the connections to the filter/separator or floor drains, but a liquid seal will be effected by the extension of the fill stem to within 6 inches of the bottom of the collection tank. The tank will be provided with an atmospheric vent and a combination stick-gage and cleanout pipe with watertight locking fill cap. The collection tank will be installed at an elevation that will insure a minimum pitch of 1/4 inch per foot for all connected drain piping. Method of installation, protective coating, and venting will be as heretofore described for horizontal underground tanks.

3-7. PIPING SYSTEMS. Materials used in piping systems will be capable of withstanding the pressures to which the system will be subjected. Pipelines will be adequately supported and secured against displacement. Adequate means of relieving linear expansion and contraction of the piping will be provided. This requirement is of particular importance for piping installed in inclosed pumprooms and pits. Piping for pump stations and pipelines will be based on the pressure requirements of USA Standard B31.3, "Petroleum Refinery Piping," and USA Standard B31.4, "Oil Transportation Piping."

a. Sizing of Pipelines. Sizing of piping for all products will be based on the selection of pipe diameter at which the rate of flow will not exceed a velocity of about 7 f.p.s., except where the pipe is reduced in size for connection to pumps, meters, and other mechanical equipment, and where products are received at a bulk storage tank farm from seagoing tankers. Piping for tanker unloading will be based on the selection of pipe diameter at which the rate of flow will not exceed a velocity of approximately 12 feet per second.

b. Pipe. Black carbon-steel pipe will be used for the fuel pipe lines, with the following exceptions: Aluminum, or internally coate steel pipe, or corrosion resisting steel, or glass fiber reinforced plastic pipe will be used for aircraft engine fuel pipelines on the downstream side of the final filter/separator of hydrant refueling systems, and to truck-fill stands. Aluminum or glass fiber reinforc plastic pipe, or internally coated steel pipe, will be used for submarine pipelines for tanker unloading facilities. Zinc coated or copper pipe and fittings, or copper tubing, will NOT be permitted in fuel handling systems.

c. Joints. Pipes smaller than 2 inches diameter will be threa and the connections with fittings will be screwed. Steel or aluminu pipe 2 inches and larger will be jointed by butt welding or flanging and all connections with fittings will be by welding. Glass fiber reinforced plastic pipe with fittings of the same material or of aluminum or corrosion resisting steel will be joined as recommended by the manufacturer. Flanged joints will not be permitted on underground lines except where the joint occurs in a valve or equipment p Insulated flanged joints will be used where metal pipelines are to b cathodically protected, to isolate the underground piping from the aboveground piping.

d. Fittings. Changes in direction of threaded piping will be with threaded fittings. Black malleable iron fittings will be used threaded steel or wrought iron pipe, and aluminum fittings will be us with threaded aluminum pipe. Changes in direction of welded piping be made by welding fittings of the same material as the pipe. Chang in direction of glass fiber reinforced plastic pipe will be made by fittings of the same material as the pipe or of aluminum or corrosi resisting steel. For pipe 2 inches and larger, changes in directior of 45, 90, 135, and 180 degrees will be made by long-radius elbows. Other angles of turn will be made by cutting down an elbow of a gree degree of turn to the proper angle. Long-radius, fabricated bends n be used in lieu of elbows where space limitations permit or where lc radius bends are required to accommodate pipeline scrapers. Branch will be made by reducing tees or forged welding branch outlets. Red or increasers in horizontal or sloping lines will be eccentric type,

stalled flat on the bottom for all pressure and gravity lines, and flat on top for all pump suction lines. Concentric-type reducers or increasers will be used for vertical pipes. Welding neck flanges will be used, except where space limitations require the use of slip-on welding flanges. Grooved fittings and couplings will be used to provide flexibility at the pump suction and discharge connections. Socket welding fittings will be used in piping systems of diesel generator sets.

_e_. Grading of Pipelines. Piping for gravity unloading of tank cars or tank trucks will have a continuous pitch down from the unloading connections to the tanks into which the product is to be received. When the tank car or tank trucks are to be unloaded by means of installed pumping units and gravity flow to the pumps is possible, the piping will have a continuous pitch down to the pump suction. When local topography does not permit gravity flow to the pumps, the unloading piping, with the exception of the risers at the unloading points, will have a continuous slope up to the pump suction. Withdrawal pipelines from aboveground-installed tanks to connected pumping units will have a continuous pitch down from the tank nozzle to the pump suction connection. Suction pipelines from underground tanks to aboveground-installed pumping units will have a continuous pitch up from the tank to the pump suction. Piping on the suction side of aircraft-defueling pumps will have a continuous pitch down from all related hydrant-lateral outlets to the pump suction whenever this can be accomplished without increasing the depth of the hydrant-lateral-control pit beyond 4 feet, 6 inches. When this is not possible, this piping will pitch up from all related hydrant outlets to the defueling pump suction. Recommended minimum pitch is 1 inch per 50 feet. No specific pitch is required for cross-country pipelines.

_f_. Bleeder and Stripper Connections. Piping systems for tank car, tank truck, and hydrant refueling systems will have a bleedoff for entrapped air at each high point, and for evacuation of water or fuel from each low point. When the high point does not occur at a connection with a pump or equipment fitted with a manual or automatic means of air release, a connection to an aboveground tank, or a valved-end riser, the high point will be fitted with a 3/4-inch manually valved bleeder connection. When the low point does not occur at a pump, a connection to an underground

tank, or valved-end gravity line, the low point will be fit d with a 2-inch manually valved stripper connection with threa - ing suitable for the attachment of a suction hose. Bleeder and stripper connections for underground pipelines will be installed in pits that permit access to the connection and e product line. Pits will be provided with watertight cover struc tures capable of supporting anticipated loads.

g. Underground Pipelines. Underground fuel pipelines will not run under floors of pumphouses, filter/separator buildings, or other such structures, and routes of these pipelines will avoid possible s es for facilities of this nature. Metal piping installed underground o under water will be externally coated. Minimum earth cover for unde ground pipeline will be 2 feet measured from top of pipe to finished grade in unpaved areas; 1 foot to underside of the paving when installed in areas to received rigid pavement, and 3 feet when install under areas to receive medium-load Air Force flexible pavement. Protective sleeves will be provided where the piping crosses under rail roads or highways. Sleeves will extend at least 10 feet from center line of the nearest railroad track or beyond the toe of the shoulder of a highway. Sleeves will be provided with a ven at each end. Underground piping will be anchored against m e- ment by welding to structural members embedded in concrete ere the piping passes through walls of pits, or where lateral m e- ment of the pipeline would place undue strain on branch-pip connections and risers. Piping passing through concrete wa s of pits will be centered within sleeves. Piping passing th ugh earth or concrete dikes will be provided with a 1/4-inch-thick steel plate fitted and continuously welded to the pip so as to act as a waterstop. The outside diameter of the p te will be at least twice that of the pipe.

h. Aboveground Pipelines. Fuel lines above ground will be su ported on structural-steel bents set into concrete footings carried to below the frostline and to undisturbed soil capable of supporting the imposed loads. Piping in buildin and in equipment pits will be supported from the floor. Interior piping will not be supported by hangers attached to the building roof. Maximum spacing between pipe supports w l be such that sag in the piping will not adversely affect th pitch of the pipe. All aboveground piping will be anchored against movement that would put strain on connections to ta s, equipment, or structures, or at points where the piping pas s through dikes. Fill and withdrawal pipelines will not be

connected to nozzles of aboveground tanks until after the tank has been preloaded with water or fuel. Ball joints, or loops or offsets in pipe runs will be used to compensate for linear expansion or contraction, or for vertical movement resulting from settlement of tanks. Bellows-type expansion joints or grooved fittings and couplings will not be used for this purpose. Piping passing through masonry or concrete building walls or concrete floors of buildings will be centered in sleeves, and sealed between the pipe and sleeve.

i. Block Valves. Block valves will be used in the product piping systems to control flow and to permit isolation of equipment for maintenance and repair. These valves will be manually operated, except where motor operators are specifically authorized by applicable standard drawings or technical specifications. Block valves will be provided at the following locations:

(1) On the abovegrade piping at each tank-car, tank-truck, barge, or tanker unloading connection. This requirement will not apply to gravity unloading lines unless block valves are specifically called for on applicable drawings.

(2) On the abovegrade piping at each tank-car, tank-truck, barge, or tanker loading connection.

(3) On the upstream and downstream side of each line blind at connections to cross-country pipelines.

(4) At the fill and withdrawal nozzles of each aboveground tank. The use of valves automatically controlled by the liquid level in aboveground or underground bulk-storage tanks will not be permitted.

(5) Immediately upstream of each float-operated liquid-level control valve on the fill lines to underground tanks.

(6) On each branch line at the point of connection to the main product pipeline or header.

(7) On the main product pipeline or header just before the line leaves a pumping station.

(8) On each main distribution pipeline immediately downstream of the branch connection to each existing or future operating storage facility served by the pipeline.

(9) At intermediate points of approximately 10 miles in cross-country distribution pipelines to facilitate isolation of a section of the line for maintenance and repair.

(10) On each side of water crossings, and near the shoreline of a submerged sea pipeline.

(11) On the suction side and discharge side of each pumping uni excepting the suction side of vertical centrifugal pumps installed in underground tanks.

(12) On the inlet and outlet connection of each line strainer, filter/separator, meter, automatic valve, and other equipment that requ es periodic servicing. This requirment will be waived when the equipment is installed in a line that can be drained by gravity to a storage tank. When two or more of the above items of equipment are installed in immediate sequence, the block valves will be installed on the upstream and downstream sides of the sequence. A block valve will also be provided between the product piping and an air eliminator installed in conjunction with one or more receiving pumps when the air eliminator is not built integral with the pump.

j. Specialized Valves. Valves for automatic regulation of line pressure, rate or direction of flow, or other specialized functions will be provided where shown on applicable standard drawings. Piping fitted with a pressure-relief valve will be provided to connect the upstream and downstream piping where normally closed valves prevent relief of excess line pressure back to storage. All pressure-relief valves wil be adjusted to open at a pressure approximately 10 percent above maxim operating pressure of the line. A swing check valve installed to prevent flow from the tank will be provided between the tank and the pressure-relief valve in the bypass piping around block valves installed at the fill or withdrawal nozzles of all aboveground tanks. Manually operated valves will not be permitted in any pressure-relief piping.

k. Strainers. Line strainers for the suction piping of each receiving, transfer, dispensing, main pipeline or booster pump, will be provided with a basket strainer having No. 7 (0.103-inch) perforations. Duplex line strainers will be provided on the suction piping of main

pipeline or booster pumps. Line strainers fitted with 40-mesh baskets will be installed in the fill line to each Air Force underground methyl alcohol storage tank. Line strainers fitted with 100-mesh baskets will be installed on the upstream side of each filter/separator, and on alcohol and water-alcohol truck-fill stand outlets, and on the fill lines to underground operating storage tanks for Army aviation installations. Line strainers with 60-mesh baskets will be installed on the upstream side of each meter for alcohol dispensing. Fuel received at a bulk terminal from a multiproducts pipeline or from a sea unloading pipeline will pass through a duplex strainer of the jet type, self-cleaning design with 200-mesh baskets, or a centrifugal-type solids separator. Waste from these types of strainers and separator will be connected to an underground slop tank.

l. Tests for Fuel Piping. Fuel piping systems will ordinarily be tested for leaks with air. Under certain conditions, the piping system may be tested with a light high-flash petroleum product. Testing for leaks with water will only be permitted on cross-country pipelines where adequate measures are taken to prevent freezing and where complete removal of the water can be accomplished after testing.

3-8. PIPELINE EQUIPMENT. The following pipeline equipment will be provided:

a. Receiving Pumps. Pumps used for unloading tank cars and tank trucks are identified as receiving pumps. All receiving pumps will have a capacity of 250 gallons per minute, and will be electric motor driven. Except for administrative gasoline, two pumps will be provided for each kind or grade of fuel to be received. One pump will be provided for administrative gasoline at these locations. The number of pumps to be provided at area reserve tank farms will be as authorized. These pumps will be either the vane-priming horizontal centrifugal type with integral air eliminator, or the sliding-vane rotary type. Design for installations using the latter type will provide an air eliminator in the main product delivery piping from the pumphouse to the storage tanks

b. Bulk-Transfer Pumps. Pumps for transfer of product from aboveground or underground bulk fuel storage tanks to tank-car and tank-truck fill stands, to barge and tanker loading docks, to cross-country pipelines, or to operating storage tanks of hydrant-type aircraft refueling systems, are identified as bulk-transfer pumps. Transfer pumps for withdrawals from aboveground tanks will be the plain horizontal centrifugal type. Vertical centrifugal pumps installed in the tank will be used for deliveries from underground tanks. Pumping equipment of 500 g.p.m. capacity will normally be provided for the bulk transfer of fuel. The number of pumps to be provided for each type of fuel will be as follows: one for each truck-fill loading position; one for each tank-car loading position but the total shall not exceed two; one for transferring fuel to each operating pumphouse of a hydrant refueling system for aircraft, and one standby for all operating pumphouses using the same fuel. Manifolding of these pumps will be arranged so that they may be used to transfer fuel within the tank farm. These pumps will be electric-motor driven. The number and capacities of pumps to be

provided for cross-country pipeline operations, and for barge and tanker offloading, will be determined for each military installation.

c. Operating Transfer Pumps. Pumps for transfer of product from underground operating storage tanks to refueling outlets of hydrant-type aircraft-refueling systems, or to truck-fill stands for Air National Guard and Army Aviation installations, are identified as operating transfer pumps. Operating transfer pumps for Air Force hydrant-type aircraft-refueling systems or Air National Guard will be vertical centrifugal units installed in the tank. Except for single-outlet hydrant-type aircraft-refueling systems for heavy bombers, pumps for hydrant-type aircraft-refueling systems and for Air National Guard truck-fill stands will have a capacity of 300 g.p.m. Pumps for single-outlet heavy-bomber-refueling systems will have a capacity of 600 g.p.m. Pumps f Army Aviation installations will be vertical centrifugal unit vane-priming-type horizontal centrifugal units or sliding-van type horizontal rotary units with capacities of 200 g.p.m. A operating transfer pumps will be electric motor driven.

d. Defueling Pumps. Defueling pumps are required for Air Force multiple outlet hydrant type aircraft refueling systems to assist the aircraft engine feed and transfer pumps to discharge fuel from the aircraft to the operating storage tanks of the installed refueling system. These pumps will be electric-motor driven, 200 g.p.m. capacit fo for the medium bomber aircraft configuration, and 300 g.p.m. capacity for heavier cargo aircraft configuration, and will be of the self-priming horizontal centrifugal type.

e. Main Line and/or Booster Pumps. These pumps are required for barge or tanker loading and unloading, or for cross-country pipelines. These pumps are usually the multi-stage, horizontal split case with a gear box designed for increasing or decreasing the pump speed, depending on the type of prime mover used. The flow and head capacities will depend upon the local requirements of the installation. Where electric power is economically feasible, the pum will be electric motor driven. At other locations the prime mover ma be a diesel engine or turbine engine. A standby main line pump or booster pumps is desirable, for reliability.

f. Filter/Separators. Filter/separators will be installed in all systems dispensing aircraft engine fuels. One 300 g.p.m. unit will be provided with each operating transfer pump for dispensing to Air Force aircraft refueling systems of the multiple-outlet hydrant design, and of the single-outlet hydrant design. One 600 g.p.m. filter/separator will be provided with each two operating transfer pumps of Air Force single-outlet hydrant refueling systems for mediu

bombers and cargo aircraft, and for each operating transfer pump of Air Force single-outlet hydrant systems for heavy bombers. Two 600 g.p.m. filter/separators will be provided in the fill piping manifold of operating storage tanks for Air Force and Air National Guard hydrant refueling systems. One 600 g.p.m. unit will be provided for each truck fill stand outlet at Air Force installations. One 600 g.p.m. will be provided for each product for each tank car loading position, but the maximum number will not exceed two 600 g.p.m. filter/separators per product. For Air Force installations where the portable carts are used to connect the installed hydrant-type refueling system to the aircraft, one 600 g.p.m. filter/separator will be installed to supply each single-outlet type of refueling system. Filter/separator capacities at Air National Guard installations will be 300 or 600 g.p.m., as determined by the amount of fuel stored. The 300 g.p.m. unit will be provided for the least amount of fuel stored, and the 600-g.p.m.-capacity unit will be provided for the larger amount of fuel stored. Filter/separator units for Army Aviation installations will be 300 g.p.m. capacity for each grade of fuel that will be dispensed. Piping from the water-discharge valve of each filter/separator will be extended to discharge into an open-end riser of the underfloor collection system. Piping from the pressure-relief valve of each unit will be fitted with a sight glass and extended to discharge into the same open-end riser as the water-discharge line, or connected to discharge into the fill stem of a related operating storage tank. Manually operated valves will not be permitted in the pressure-relief lines. Adequate clearance will be maintained between the top of the filter/separator and the housing-structure roof for removal of cartridge elements from the filter/separator, and between the filter/separator vessel and the walls to permit rotation of the vessel flanged head.

g. Meters. One 600 g.p.m. capacity meter equipped with ticket printers will be provided for each truck fill stand and each tank car fill stand outlet at Air Force tank farms. Rate-of-flow controllers set to limit maximum delivery through the meter to 600 g.p.m. will be provided where it is possible for the dispensing system to deliver in excess of this rate to the meter. One 300 g.p.m.-capacity meter will be provided for each truck fill stand outlet at Air National Guard installations and at Army installations when dispensing to contract operated tank trucks. The meters will be the one-way-flow volumetric positive-displacement type; air eliminators are not required with these meters. One 600 g.p.m. capacity meter will be provided for each hydrant outlet of Air Force single-outlet hydrant-type aircraft refueling systems. These meters will be the two-way-flow volumetric positive-displacement type.

3-9. TRUCK FILL STANDS. Truck fill stands will be single-outlet type or double-outlet type. Single-outlet stands will consist of a structrual-steel platform capable of withstanding a load of 100 pounds per square foot, with a stairway from ground level to the platform. Top loading of trucks will normally be required except for Air Force installations both

bottom and top loading are required. For top loading, the fill stand will be provided with a counterbalanced drop walkway for access to the truck dome from the platform. The truck loading outlet will consist of a telescoping loading arm assembly with a spring loaded self-closing throttle valve, a riser pipe for supporting the loading arm assembly, upstream and downstream manually operated valve, and upstream line strainer. Double outlet truck fill stands will have drop walkways and truck loading outlets on each side of the platform. The bottom loading connection will branch from the top loading riser and will be provided with a manual shutoff valve and an aluminum counterbalanced horizontal swivel type loading arm. A pressure switch will be provided in the branch piping to automatically shut off the transfer pump when the bottom loading valve on the truck closes. A start-stop switch will be provided on the platform, and another start-stop switch will be accessi e from ground level, at the stand. Canopies will be provided for truck fill stands. The minimum distance between a truck fill stand and a pumphouse or a filter/separator building will be 30 feet. The pavement on which trucks will park for loading at each fill stand must be level longitudinally, but may have a transversal pitch.

3-10. VALVE AND EQUIPMENT PITS. When pits are required for valves and equipment installed in underground pipelines, they will be limited to a maximum depth of 4 feet 6 inches. The only exceptions will be where deeper pits are required to provide headroom for the installed equipment. In cases of high ground water, the pits will be provided with a concrete bottom, and membrane waterproofing will be applied to the bottom and below-grade portions of the walls. The walls of the pit will extend 6 inches above grade, and the area surrounding the pit will be sloped away to prevent surface water and debris from entering. Watertight covers will be provided. In areas subject to high winds or blast from aircraft, devices will be provided to lock the covers in both the open and closed positions. Valve and equipment pits will not have installed lights, forced-air ventilators, or sump pumps unless this equipment is specifically called for on the applicable standard drawings. Connection of drain piping from such pits to sanitary sewers or storm drains will not be permitted.

3-11. ELECTRICAL FACILITIES. These facilities will be as shown on applicable standard drawings when such drawings are available. When standard drawings are not available, or when specific details are not shown on such drawings or covered herein, electrical facilities will conform to TM 5-811-1/AFM 88-9, Chapter 1 (formerly designated as EM 1110-345-181), to TM 5-811-2/AFM 88-9, Chapter 2 (formerly designated EM 1110-345-182 Because of the hazardous nature of these facilities, extreme caution will be exercised in the design of the electrical sys m. The installation of receptacles, floodlights, handholes, over head or underground lines, or other electrical devices where

a fuel spillage is likely to occur, such as in or near pumprooms, truck-fill stands, etc., will be avoided unless it is clearly evident that such equipment is necessary for the proper functioning of the system. Distances, elevations, and requirements indicated herein are to be considered minimum requirements under average conditions. Prior to the construction of any fueling facility, a careful site survey will be made to determine if topography or wind conditions would be likely to create a hazardous condition to general-purpose electrical equipment located within 1,000 feet of the source of hazardous fuel. If investigation proves that a hazardous situation is likely to exist because of these factors, consideration will be given to increased elevation, relocation to avoid the hazard, or to making the equipment completely explosion proof.

☆ a. Hazardous Locations. Electrical equipment, or overhead conductors therefor, will not be permitted inside of the diked area for an aboveground engine-fuel storage tank. Motor-pool filling stations and commissary service stations will comply with requirements of Article 510 of the National Electrical Code. Totally inclosed electrical equipment and wiring as required by the National Electrical Code for Class I, Division 1, hazardous locations where Group D (with maximum temperature rating to suit the fuel handled) atmospheres are present, or likely to be present, will be provided as follows:

(1) Within inclosed-type pumprooms and filter separator buildings, and outdoors to a height of 15 feet above grade and a distance of 25 feet horizontally from the discharge point of the forced-air ventilating-system exhaust fan. An exception will be made in the case of exterior overdoor lights and heating elements in the air supply duct. These lights will be provided with a suitable guard against mechanical damage and will be vapor-proof inclosed. Heating elements in the air supply duct located on the roof of a pump room or filter/separator building will be of the general-purpose type.

(2) The area beneath the canopy of open-type pumprooms and filter/separator shelters, and outside to a height of 4 feet above grade and for a distance of 20 feet horizontally beyond.

(3) The area of outdoor unsheltered pumping stations to a height of 4 feet, and to this height above grade for a distance of 20 feet horizontally beyond.

(4) In valve and equipment pits and to a height of 4 feet above, and for this height above grade for a distance of 20 feet horizontally beyond. An exception will be made in the case of the 24- or 48-volt electrical control cables and the pull, receptacle, and switch boxes at the refueling points of Air Force hydrant-type refueling systems. This equipment will be as indicated on the standard drawings for these systems.

(5) At truck or tank-car unloading connections to a height of 4 feet above grade, and to this height for a distance of 50 feet horizontally beyond.

(6) At truck-fill stands and tank-car loading racks to a height of 15 feet above the highest point on the structure, and to this height for a distance of 50 feet horizontally beyond.

(7) At unloading or loading docks for barges and tankers to all elevations and for a distance of 50 feet horizontally beyond.

(8) Within 20 feet from the vent of an underground tank. An exception will be made in the case of exterior overdoor lights at pumphouses or filter/separator buildings. These lights will be as described above in paragraph 3-11a(1).

(9) The entire aircraft-parking-apron area that contain fueling outlets. For large aprons, some portions of which contain fueling outlets and other portions of which do not, the hazardous area will be considered as extending 200 feet from the nearest fueling point. In compliance with this requirement the following criteria will be followed:

(a) Electrical manholes in parking, fueling, and maintenance aprons will not be permitted.

(b) All cableways and electrical devices, includin those for communications, navaids, commercial power, etc., exce those reserved to serve hydrant refueling systems and apron pow receptacles will be installed beyond the periphery of aprons.

(c) Existing electrical manholes in aprons where fueling systems are to be installed will be demolished, filled, and paved over, if they will be within 200 feet of a fueling point.

(d) Electrical manholes installed along the periphery of an apron will be located so they are not less than 50 feet from the edge of the paving and not less than 50 feet from any hydrant lateral control pit.

b. Nonhazardous Locations. Except in the hazardous locations listed above, electrical equipment and wiring will be general-purpose inclosed. Inclosures for outdoor equipment will be the weather-resistant type. Electrical equipment for nonhazardous locations will be installed at a minimum height of 4 feet above grade or 4 feet above the floor when installed indoors, except outdoor pad-mounted transformers.

c. Transformer Station. Transformer stations will be the outdoor type at all locations. Such stations will be pole or platform mounted or installed at grade on a concrete pad. Special protection will not be provided for transformer stations installed in conjunction with atomic-blast-resistant-type facilities. Sizing of transformers will be based on 100 percent demand.

(1) Pole-mounted installation. In order to avoid the hazard to other facilities of a fallen pole or primary power conductor, pole-mounted transformer stations will be located so that the supporting pole, or poles, will be a minimum distance of 50 feet from:

(a) A pumphouse, filter/separator building, or other such structures.

(b) A valve or equipment pit.

(c) An abovegrade fuel-system manifolding or pumping station.

(d) The pavement on which tank trucks will park for unloading or filling, and the unloading connections or fill stands related thereto.

(e) The section of spur track on which tank cars will be spotted for unloading or filling, and unloading connections or loading racks related thereto.

(f) A barge or tanker berthing dock.

(g) The centerline of a dike.

(h) The area under which a tank is buried.

The above requirements will further apply to the routes for aerial primary power supply, the 50-foot distance to be as measured horizontally from the line of the overhead wiring. Such lines will not be routed over diked areas, or any of the structures or areas listed above.

(2) Pad-mounted installation. Concrete-pad-mounted transformers will be fence inclosed, the total height of the fence to be 7 feet. In order to provide a safe passage for personnel within the fence, the length and width dimensions of the fence will be as required to provide a minimum clear distance of 3 feet from the fence to any of the inclosed electrical apparatus. A distance of 4 feet will be maintaine . between the fence and the related pumphouse or filter/separat building. An entrance gate with suitable hardware for lockin will be provided in one end of the fence. The gate will be o sufficient width to permit removal of the transformers. Prim ry power supply for a distance of at least 50 feet from outside of the fence and the related building will be underground in order to remove the hazard of a fallen pole or primary conduc or.

d. Provisions for Receiving Emergency Power. Air Force installations will be provided with facilities for receiving emergency power from portable generating equipment. At abov ground tank farms, water-alcohol systems, and hydrant-type aircraft-refueling systems, these will consist of a three-pole, double-throw switch installed so as to permit selectio of the transformer station or the portable generator as the source of power. A three-pole, single-throw switch will be provided on the portable generator side of the three-pole, double-throw switch. The purpose of this switch is to provi e a means of disconnect between the portable generator and the double-throw switch during attaching and removing of the fee er cable from the portable generator. When pole-mounted transformers are provided, these switches will be mounted on the transformer pole, or poles. When pad-mounted transformers are provided, the single-throw switch will be mounted outdoo s on the near wall of the related control room, and the double throw switch installed in the control room alongside the mai circuit breaker. At underground tank farms, provisions for receiving emergency power will be as indicated on the standa d drawing. These switches will be no nearer than 50 feet to a

pump pit or 20 feet to a tank vent. The above switches will be the nonfused type. Provisions for receiving emergency power will not be provided at Air National Guard or Army Aviation installation.

e. Secondary Power and Control Systems. Exterior secondary wiring will be installed underground, except where otherwise indicated on the standard drawing. Wiring and equipment for secondary power and control systems will be in accordance with the following requirements.

(1) Wiring methods. Underground conductors will be run in nonmetallic conduit, except where rigid conduit will be more economical for small-size conductors. Rigid conduit will also be used for changing from underground to aboveground exterior wiring and for underground connection to embedded metallic equipment housings. Nonmetallic conduit for installation underground will be a type suitable for burial without concrete encasement, except where used for Air Force hydrant-type aircraft-refueling systems. In these instances the conduit will be encased in concrete in order to provide additional protection for the conductors of these systems. Reinforcement will not be provided for the concrete encasement. Interior wiring for pumphouses and filter/separator buildings, and wiring inside of valve and equipment pits will be run in rigid conduit. Such conduit will be extended out of the building to a point 5 feet beyond the exterior wall for connection with underground nonmetallic conduit. Rigid conduit in valve and equipment pits will be extended a sufficient distance beyond the exterior pit wall to permit connection with nonmetallic conduit on the outside of the pit. Suitable adapter fittings will be provided for all connections between rigid and nonmetallic conduit.

(2) Control station. Selector switches that permit local or remote control of pumps dispensing to truck fill stands, tank car fill stands, and hydrant-type aircraft refueling system pumps, will be installed alongside the related motor starter. These switches will be the Hand-Off-Automatic type. Remote control of pumps for dispensing to tank car fill stands and truck fill stands will be Off-On pushbutton switches installed on the fill stand adjacent to the loading outlet piping. Remote control for hydrant-type aircraft refueling system pumps will be from the refueling point. Local control only will be

provided for receiving pumps, or to locations other than fill stands. Off-on pushbutton switches installed alongside the related motor starter will be provided for these purposes. A pushbutton switches will be the momentary-contact type. Auxiliary control for pumps at booster stations for tanker unloading lines and for cross-country pipelines will b as required for satisfactory operating of the booster pumps.

(3) Low-liquid-level switches. A low-liquid-level switch installed as part of the float-operated tank gage will be provided for each underground bulk fuel storage tank and each operating storage tank of mechanical systems. The funct of this switch will be to stop the related pump, or pumps, wh the liquid in the tank has been drawn down to a predetermined low level.

(4) Motor-disconnect means. Unless the motor starter and circuit breaker are installed in the same pit or room, or outdoors adjacent to the pump, a motor-disconnect means will be provided at each pump. A circuit breaker or horsepower-rated switch will be used for this purpose. A switch that interrupts only the control circuit will not be acceptable for this additional disconnect means.

(5) Emergency-stop stations. Emergency pushbutton stations wired to permit simultaneous shutdown of all relate pumping equipment under circumstances warranting such action will be provided at each truck-fill stand, tank-car loading rack, and underground tank farms, and at Air Force hydrant-type aircraft-refueling systems. The pushbuttons for these stati will have normally closed contacts and will be of the moment contact type. Emergency-stop stations will be located as fc

(a) Truck-fill stands. 4 feet above grade and 25 feet horizontally from the foot of the fill-stand stairs.

(b) Tank-car loading racks. At the foot of the stairway at each end of the rack.

(c) Underground tank farms.

1. Control building. On the exterior wall adjacent to the door, 5 feet above grade.

2. Truck-loading building. 4 feet above g on the far side of the adjacent service road, 15 feet from the centerline of the road.

3. Manifold station. 4 feet above grade on the far side of the adjacent service road, 15 feet from the center-line of the road.

(d) Multiple-outlet hydrant refueling systems.

1. At each fueling point in the cover of the embedded combination pull, receptacle, and switch box.

2. Post-mounted outside of each hydrant lateral-control pit at a height not to exceed 18 inches above grade.

(e) Single-outlet hydrant refueling systems. Inside and just below the cover of each hydrant-meter pit of systems for single fighters and double fighters, or inside and just below the cover of each hydrant filter/meter pit for systems for medium bombers and transports or heavy bombers.

f. Grounding. The design of the engine fuel handling system will include grounding of the installed electrical system and static grounding of the fuel piping system. Fuel pipelines installed below ground will be electrically isolated from the equipment grounding system through the medium of insulating flanges installed above ground in the vicinity where the pipe rises to the surface.

(1) Electrical equipment grounding will be accomplished in accordance with the National Electrical Code. A dielectric fitting will be installed in the metallic water service at the point of entrance to the building, to electrically isolate the interior piping from the exterior system. The interior metallic cold water piping will be grounded to one or more ground rods, as required to meet the National Electrical Code requirement for ground resistance not to exceed 25 ohms where practicable.

(2) Static grounding for the aboveground fuel piping system, appurtenances and metal structures, will be accomplished using a 3/4-inch copper clad steel ground rod not less than 8 feet long. The rod will be driven vertically into the earth so that the top of the rod is one foot below the finished grade. There will be no requirement with respect to maximum resistance to ground. Underground coated metal pipelines will not be bonded to the static grounding system.

(3) Specific grounding requirements. The resistance to earth, an corrosion characteristics of ground rods are covered in TM 5-811-4/AF 88-9, Chap. 4, "Corrosion Control." Bare, soft-drawn copper conduct sized in accordance with the National Electrical Code for service entran equipment, will be used for all aboveground connections. Grounding con tors installed below ground will be sized as above but provided with an lated jacket to prevent corrosion. Further requirements for specific lo are as follows:

(a) Pole-mounted transformer stations. The lightning arrest will be separately and independently grounded from the equipment groun both systems will be bonded together at the ground rod terminals. The bined resistance to ground will not exceed 25 ohms where practicable. round wood or plastic molding will be provided to protect the grounding ductors. This molding will extend from the ground line to a point at lea feet above the ground line and throughout the communication and transf spaces, and will be stapled to the pole at intervals not exceeding 2 feet one staple not more than 3 inches from each end.

(b) Pad-mounted transformers. The transformer-inclosure the corner fenceposts, the gate, the primary feeder conduit and pothea primary fused cutout support structure, the transformer case or cases the secondary wireway will be bonded together and connected to ground resistance to ground will not exceed 25 ohms where practicable.

(c) Pump stations. The center tap of the lighting transform each electrical distribution system will be provided with a separate an pendent conductor connected directly to the ground electrode. All elec equipment inclosures, conduit, the fuel piping above ground, the meta work of the building and all related metal items such as floor-drain fr and floor washers, will be bonded together, and connected to the same as described above. All pumps, motors, filter/separators, meters, particle filters, line strainers, valves, and heating and ventilating eq will also be grounded when these items are not effectively bonded toge the piping or conduit connections in conformance with the National Ele Code. In addition, underground operating storage tanks located under jacent to a pump house will be electrically isolated from the groun system. These tanks will be cathodically protected. See TM 5-811-4 88-9, Chap. 4, "Corrosion Control," for guidance.

(d) Aboveground fuel storage tanks. Grounding connection aboveground fuel storage tanks mounted on concrete pedestals above g will consist of a grounding conductor attached to the shell of the tank end and to a single ground rod located approximately 3 feet out from t of the tank. There is no requirement regarding maximum permissibl resistance of ground rod to earth. Tanks in contact with the earth wi require grounding.

(e) Spur track for unloading or loading tank cars. When a spur track is required for unloading or loading tank cars, a rail-joint insulator will be provided for each rail at the first rail joint beyond the turnout from the related main line or base railroad track. The purpose of these insulators is to prevent the flow of stray electrical current from the main track into the tank-car spur track. The rails at all other joints in the spur track beyond the insulated joints will be bonded together, and both rails of the bonded spur track will be connected by grounding conductors to a single driven ground rod. There is no requirement regarding maximum resistance of ground rod to earth.

(f) Tank-car unloading positions. The fuel-piping unloading connections at each tank-car unloading position will be bonded together and connected by means of a grounding conductor to the spur track. A 20-foot length of No. 8 AWG, type S, flexible 49-strand, conductor will be provided for grounding the tank car. One end of this conductor will be bonded to the fuel piping and the other end will be fitted with an alligator clip for attachment to the tank car. A metal post fitted with suitable brackets for holding the coiled conductor when not in use will be provided at each unloading position.

(g) Tank-truck unloading positions. Requirements for grounding at tank-truck unloading connections will be in accordance with instructions for tank-car unloading connections, except that the bonded fuel piping will be connected to a driven ground rod located adjacent to the unloading connection or connections. There is no requirement regarding maximum resistance of ground rod to earth.

(h) Truck-fill stands. The fill-stand structure, the electrical conduit, and the fuel piping will be bonded together and connected by means of a grounding conductor to a metallic water pipe or driven ground rod. There is no requirement regarding maximum resistance of ground rod to earth. A 10 foot length of the same kind of cable described in the preceding paragraph (f) for grounding tank cars will be provided for grounding the truck. This cable will be bonded to the permanent grounding conductor at one end and shall be fitted with an alligator clip for attachment to the truck tank at the other end. Brackets suitable for holding the coiled wire will be provided on the rack. One such truck-grounding wire will be provided at single-outlet truck-fill stands; and two such wires, one on each side of the stand, will be provided at double-outlet truck-fill stands.

(i) Tank-car loading racks. Grounding at tank-car loading racks will be in accordance with instructions for grounding at truck-fill stands, except that the grounding conductor will be connected to the tracks and the length of the cable for attachment to the tank car will be 20 feet.

(j) Barge docks and marine tanker piers. The fuel pipe- lines, electrical conduit and equipment inclosures, and the framework of the dock or pier, if metal, will be bonded together and grounded in con formance with the National Electrical Code. A flexible copper welding type cable will be provided for connecting the vessel to the shore groun ing system. the shore end of this cable will be permanently attached t an explosionproof safety ground control switch, and the other end will b fitted with a clamp for attachment to the ship. The clamp will have serrate jaws, adjustable to a maximum opening of 2 inches. The ground control switch will be connected to the shore grounding system and will be kept in the open position until after the shore-to-ship grounding cable has been clamped to the vessel. No additional grounding is necessary.

(k) Apron refueling points. The electrical-equipment housing, and the cover frame of the refueling-hydrant outlet pit will be bonded together and connected to a combination tiedown and ground rod. Maximum permissible resistance to ground will be 100,000 ohms.

(l) Equipment pits. Electrical conduit, motor frame and mechanical equipment shall be bonded together and grounded. There i: no requirement regarding ground rod resistance to earth. The undergrour metal piping system will be isolated from the electrical grounding system by installing insulated flanges in the fuel piping inside the pit.

(m) Fence enclosing the area. A grounding connection will be provided at each corner of the perimeter fence, on each side of all gates, and at no greater than 300-foot intervals along the entire perim- eter of the fence. Each grounding connection will consist of a grounding conductor bonded to the woven wire fabric fencing and connected at the free end to either an underground metallic water pipe or to a driven groun rod. A bond will be made at each gate by attaching a No. 4 AWG insulatec copper wire to the fence fabric at one side of the gate and extending the wire underground, without splices, to a connection with the fence fabric at the other side of the gate. There is no requirement regarding maximum resistance of ground rod to earth.

3-12. OPERATIONS COMMUNICATIONS. To facilitate installing of fire-reporting and base telephones by the using service, an empty -inch rigid steel conduit will be provided. This conduit will extend under round from a point 5 feet outside the building to a stubbed-up terminus ithin the control room of Air Force receiving, transfer, and operating umphouses, and Air National Guard installations. This conduit will term iate within the pumproom of Air Force water-alcohol systems, the contro building of the Air Force hardened underground tank farms, and the filter/ separator building of Army Aviation installations. A similar conduit will

be provided to terminate within the administration office of area-reserve tank farms.

3-13. CATHODIC PROTECTION. A preliminary survey will be made to determine the need for cathodic protection for all new storage, receiving, distributing, and dispensing systems for aircraft and automotive fuels. Considerations to be taken into account when justifying cathodic protection are covered in TM 5-811-4/AFM 88-9, Chap. 4, "Corrosion Control." If cathodic protection is required, it will be installed during construction of the facility. The cathodic protection system will be designed in accordance with criteria in TM 5-811-4/AFM 88-9, Chap. 4.

3-14. SPUR TRACKS. The spur track or tracks for unloading or filling tank cars will be located not less than 65 feet from the centerline of other tracks and not less than 100 feet from the shell of an aboveground tank, or from an existing or future building not considered a part of the tank farm. The length of the spur track at the unloading or filling area will be determined by allowing 40 linear feet of track for each tank-car parking position with a minimum of 10 feet overrun at the dead end. The number of positions will be determined by the using agency, but normally will not exceed ten. (One additional unloading position at the dead end of the track is authorized by Air Force for spotting a tank car containing methyl alcohol when water-alcohol blending and dispensing facilities are constructed in the tank-farm area.) Under these circumstances, the unloading or filling positions will be in line along the track, available space permitting. When the limits of the site do not permit the construction of a single track, or where more than ten (plus one alcohol) unloading positions are authorized, two parallel tracks for spotting the tank cars will be provided In the latter event, the center-to-center distance between the tracks will be 17 feet to permit installation of unloading connections between the tracks. When tank cars are to be filled at the facility, the center-to-center distance between parallel tracks will be increased to 24 feet to permit construction of a loading rack between the tracks. In all cases, the section of track from which tank cars are to be unloaded or filled must be level longitudinally to insure complete unloading of the cars. In all other respects the design of the spur track will be in accordance with TM 5-850-2/AFM 88-7, Chap. 2, "Railroads - Army and Air Force."

3-15. ROADS. Main tank-farm service roads will be of sufficient width to permit two-way travel, and will extend to all fuel-truck unloading and loading positions and to the vicinity of all pumphouses and other important operating areas. Whenever

possible, the design of such roads will include separate entrance and exit routes. Connections between pumphouses and the main service road will be single-lane. The main tank-farm service roads and the single-lane pumphouse connections will be paved, the pavement to be rigid or flexible type except at engine-fuel truck unloading or loading positions, where rigid-type pavement will be mandatory. In addition to the above, one-way-travel fire lanes will be provided to permit fire trucks to reach piers docks, and fire hydrants at other locations in the tank farm.. Turnouts will be provided at each fire hydrant. Fire lanes and turnouts from same will not be paved. Paved single-lane service roads will be provided at all Air Force hydrant-refuelin system operating pumphouses, Air National Guard pumphouses, and Army Aviation filter/separator buildings. Additional service roads will be provided as required to permit access of fuel trucks for unloading or loading at the latter two facilities. Such roads will be routed to avoid passage over underground tanks. Pavement will be flexible or rigid type except at engine-fuel-truck unloading or loading positions. Rigid type pavement will be mandatory at these points. Roads within tank farm or other engine-fuel storage areas will not be curbed or guttered. All roads will be designed for anticipated wheel loads and frequency of travel in accordance with TM 5-822-2/AFM 88-7, Chap. 5 (EM 1110-345-290), "General Provisions and Geometric Design for Roads, Street Walks, and Open Storage Areas"; and TM 5-822-5/AFM 88-7, Chap. 3 (EM 1110 345-291), "Roads, Streets, Walks, and Open Storage Areas - Flexible-Paveme nt Design", or TM 5-822-6/AFM 88-7, Chap. 1 (EM 1110-345-292), "Rigid Pavements for Roads, Streets, Walks, and Open Storage Areas."

3-16. FENCING. Unless located in a secured area, engine fuel storage and dispensing facilities will be protected by fencing. Such areas requiring fencing will be inclosed with type FE-6 fencing designed in accordance will applicable portions of Standard Drawing No. E-40-16-07. Vehicular gates will be 2 feet wider on each side than the roadway pavement. Access for personnel to and from the fenced area will be by means of the vehicular gates when such are provided. Four-foot-wide pass gates will be provided when vehicular gates are not required.

3-17. DATA FOR THE INFORMATION OF THE USING AGENCY. After acceptance of the completed fuels-handling system by the Contracting Officer, the following data will be prepared and transmitted to the using agency:

a. As-Built Drawings. As-built drawings for all items of construction reproduced from the project tracings revised to show this information.

b. Schematic Piping Diagrams.

(1) Schematic fuel piping and pumping diagram reflecting as-built conditions suitable for mounting in each pumphouse. The diagram will include the number of each valve tag and will be of a type that can be incorporated with an operation and maintenance manual.

(2) Schematic diagram showing as-built conditions for all water-supply and drainage piping related to the facility. This diagram will be similar to the one for fuel piping.

c. Schematic Electrical Diagram. Schematic diagram showing each electrical system as-built, suitable for mounting in the pumphouse and incorporating in an operation and maintenance manual.

d. Operation and Maintenance Manuals. An operation and maintenance manual containing a description of the facility and all components; instructions for performing all operations for which the facility was constructed; instructions for servicing and repairing all valves, gages, controls, mechanical and electrical equipment, including manufacturers' installation, service, and repair parts data. The latter will include the name and address of the manufacturer's nearest service representative and make, model, and serial number of each valve or piece of equipment. This manual will also include information concerning the characteristics of the products to be handled and their effects on personnel and materials, together with instructions for fire prevention and control, and other pertinent safety precautions. The instructions contained in applicable guide manuals for the preparation of field operation and maintenance manuals issued by the Office of the Chief of Engineers will be followed in the preparation of the manual for the using agency.

b. Schematic Piping Diagrams.

(1) Schematic fuel piping and pumping diagram reflecting as-built conditions suitable for mounting in each pumphouse. The diagram will include the number of each valve tag and will be of a type that can be incorporated with an operation and maintenance manual.

(2) Schematic diagram showing as-built conditions for all water-supply and drainage piping related to the facility. This diagram will be similar to the one for fuel piping.

c. Schematic Electrical Diagram. Schematic diagram showing each electrical system as-built, suitable for mounting in the pumphouse and incorporating in an operation and maintenance manual.

d. Operation and Maintenance Manuals. An operation and maintenance manual containing a description of the facility and all components; instructions for performing all operations for which the facility was constructed; instructions for servicing and repairing all valves, gages, controls, mechanical and electrical equipment, including manufacturers' installation, service, and repair parts data. The latter will include the name and address of the manufacturer's nearest service representative and make, model, and serial number of each valve or piece of equipment. This manual will also include information concerning the characteristics of the products to be handled and their effects on personnel and materials, together with instructions for fire prevention and control, and other pertinent safety precautions. The instructions contained in applicable guide manuals for the preparation of field operation and maintenance manuals issued by the Office of the Chief of Engineers will be followed in the preparation of the manual for the using agency.

SECTION 4. STORAGE AND DISTRIBUTION

4-1. GENERAL. Fuel-storage tank farms are for the purpose of providing a reserve or operating supply of fuel. The capacity of the tank farm will depend on the requirements of the using service. Large tank farms may be classified as air-base bulk storage or area-reserve bulk storage. Area-reserve bulk storage will differ from air-base bulk storage in that it will be strategically located to supply several air-base tank farms. The general designs of air-base bulk storage and of area-reserve bulk storage will be similar except for the number and quantities of fuels handled. Storage of fuel in such facilities will be in aboveground or underground tanks as authorized. At installations where small quantities of fuel are required, the fuel will be stored aboveground or in underground horizontal tanks. Distribution of the product from the storage facilities described above may be to one or more of the following: truck-fill stands, hydrant-type refueling systems, railroad tank cars, barge or marine tankers, or cross-country pipeline. Catch basins and inlets to storm drains will not be provided for surface drainage near tank-car or tank-truck unloading positions, in the vicinity of truck-fill stands, tank-car loading racks, or where the effluent from drain lines of diked areas could enter the storm drain. Under no circumstances will the spilled or drained-off product be permitted to enter a storm drain, sanitary sewer, or electrical manhole, or to drain to a natural source of water supply. The arrangement of tanks and other tank-farm facilities shown on standard drawings referenced in following paragraphs of this section will be modified as required to conform with the tank-farm site.
* Vapor recovery systems will conform to the local and state code requirements
* See AR 200-1.

4-2. ABOVEGROUND TANK FARMS.

a. Selection of Tank Sizes. At new Air Force tank farms, one tank will be provided for all requirements of less than 10,000 barrels, two tanks for requirements of from 10,000 to 200,000 barrels, and three or more tanks for requirements of over 200,000 barrels, the capacity of the largest tank not to exceed 100,000 barrels. For additional storage to existing Air Force tank farms, one tank will be provided for authorizations of from 10,000 to 100,000 barrels, and two or more tanks with individual capacities not to exceed 100,000 barrels each for authorizations in excess of 100,000 barrels. When two or more tanks are required in the above cases, the selection of tank capacities will be such that the most economical erection costs will be obtained. For Air National Guard installations where aboveground storage is required, one tank will be provided for the authorized amount of storage.

b. Clearances. A minimum distance of 100 feet will be maintained between the shell of any tank and the tank-farm boundary line, unloading or loading areas, the centerline of any spur track, or any structure within the tank-farm area except pumphouses. The latter may be located at any point outside of the diked area. A minimum distance of 200 feet will be maintained between the shell of any tank and the centerline of any main railroad. The minimum clear distance betwee shells of adjacent aboveground vertical tanks will not be less than the diameter of the larger tank. For new tank farms and where real estate is available, the recommended center-to-center spacing for aboveground vertical tanks will be as shown in table 4-1. Distance betwee tanks of different capacities will be the sum of half the distance specified for each tank. For example, a 55,000 barrel and a 100,000 barrel tan would be installed 350 feet center-to-center, the spacing determined by adding half of 300 and half of 400.

TABLE 4-1. SPACING BETWEEN ABOVEGROUND VERTICAL FUEL TANKS

Capacity of tank, in barrels	Distance between tanks, in feet
Less than 2,500	50
2,500 but less than 5,000	75
5,000	100
10,000	130
15,000	160
20,000	180
25,000	200
30,000	220
40,000	250
55,000	300
80,000	350
100,000	400

The spacing between shells of aboveground horizontal tanks at Army insta la tions shall be not less than three feet. Except for operating storage tanks of hydrant systems at Air Force installations, the aboveground horizontal tanks shall be arranged in pairs, with a minimum clearance of 1 feet between tanks of each pair, 20 feet between adjacent tanks of two pai s placed in one row, and 40 feet between adjacent tanks of groups of four te ks placed in one row. Also, a 40-foot minimum clearance will be provided between parallel rows.

c. Foundations for Aboveground Tanks. The allowable soil loading and the subsurface construction required will be determined after a complete surface and subsurface investigation. The subgrade must be capable of sus ai ing the load of the tank and its contents without unequal or nonuniform settlement which would distort the tank and introduce stresses from exter l causes. The foundation will consist of a compacted, select material, slo d down to the center, topped with an oiled sand pad. The slope to the cente will be 3 inches in 10 feet. The diameter of the subgrade and sand pad wi l

be such that the foundation will extend for a distance of 5 feet beyond the shell of the tank. When required to stabilize the subgrade, a concrete ring wall will be provided. The ring wall will center under the tank shell and extend below the frost line. The minimum height of the tank foundation will be sufficient to put the bottom of the tank at the center at least 1 foot above the graded diked area. The height of the foundation will be increased as needed to insure flooded product withdrawal piping between the tank and the transfer pumps. Concrete splash blocks will be provided at each water-drain tank fitting to prevent erosion of the foundation.

d. Dikes. Each aboveground tank will be individually inclosed within a diked area. Dikes will normally be constructed of earthen materials and will have a capacity equal to that of the tank plus one foot of free board to allow for erosion. Materials impervious to the product will be used on the upper 12 inches of the dike top and slopes and of the entire area inclosed within the dike. All earth dikes will have a flat section at the top not less than 2 feet wide. The height of earth dikes will normally be limited to 6 feet. Concrete stiles with pipe handrails will be provided at points where passage across earth dikes is required. If materials impervious to the product are not locally available and it is not economically feasible to secure such materials, or when it is necessary to construct dikes in confined areas where lack of space precludes the construction of earth dikes, reinforced-concrete dikes may be used. In such instance the concrete dike shall have a capacity equal to that of the tank. Steel ladders on both sides of the dike with handrails at the top will be provided at points where passage over concrete dikes is required. A sump for Army installations, and an oil-water separator for Air Force installations, each constructed in concrete, will be provided at the lowest point in the dike-enclosed area, and the rest of this area will be graded for drainage to the sump or separator. The sump or separator will be connected to the outside of the dike by a drain pipe installed under the dike. The end of the drain line outside the dike will be fitted with a lock-type gate valve. The area outside of the dike will be graded for proper disposition of water drained from the diked area. Each aboveground tank will be individually inclosed within a diked area. Tanks for less than 5,000 barrels capacity may be enclosed in one dike provided the combined capacity does not exceed 15,000 barrels. The dike capacity for multiple tanks will equal the volume of the largest tank enclosed plus 10 percent of the total capacity of the others.

e. Applicable Drawings. Typical facilities for aboveground Air Force air base tank farms are shown in Standard Drawings 78-24-16, and -17 and -18. Typical facilities for aboveground Air Force area reserve tank farms are shown in Standard Drawing 78-24-23. Individual tanks will be in accordance with instructions for aboveground tanks in paragraph 3-5 hereinbefore.

4-3. UNDERGROUND TANK FARMS. Underground storage of bulk fuel in vertic tanks is intended for use where protection from atomic blast is required. Horizontal underground tanks of 50,000 gallon capacity or less, for minor bulk storage, will be used only when sufficient clearance to aboveground structures cannot be obtained. Clearances for underground vertical and horizontal tanks will be as specified in paragraph 4-2, except the minim spacing between adjoining shells, for vertical tanks, will not be less than 30 feet. A minimum distance of 25 feet will be maintained between the shell of any tank underground and: tank farm boundary line, loading or unloading area, centerline of any railroad spur track, and any structure within the tank farm area. Where the presence of rock makes excavation cost prohibitive, or where for vertical tanks the water table would be higher than 10 feet above the bottom of the tank, the tanks will be semiburied and mounded over, or surface installed and mounded over.

a. Vertical Tanks. A typical layout for an underground tank farm with components designed to resist an overpressure of 10 pounds per square inch is shown on Standard Drawing 78-24-19. Individual tanks will be in accordance with instructions for underground tanks, in paragraph 3-5.

b. Horizontal Tanks. Details for construction and installation of horizontal tanks of 50,000 gallon capacity or less are shown in Standard Drawings 78-24-01, 78-24-20, and 78-24-26. Sizes not shown will conform to the requirements of National Fire Protection Association, National Fire Code No. 30, "Flammable and Combustible Liquids Code."

4-4. UNDERGROUND OPERATING STORAGE. Underground operating storage for hydrant-type aircraft-refueling systems will be located in the proximity of the aircraft-parking apron. This type of storage is required to maintain the fuel at a lower temperature than aboveground storage, and will also be used for water-alcohol blending systems, and for Air National Guard and Army Aviation fueling systems. Criteria for these installations are contained in Section V of this manual.

4-5. FACILITIES FOR RECEIVING PRODUCTS FROM TANK CARS AND TANK TRUCKS. Products received in tank cars and tank trucks will be unloaded into aboveground storage tanks by means of pumps. Except when the difference in elevations at the unloading area and at the tanks, or the distance between these points, requires the use of pumps, products received in tank cars and tank trucks will be unloaded into underground storage tanks by gravity.

a. Tank Cars Only. If fuel is to be received by tank cars exclusively, a spur track will be built from the nearest railroad to the tank farm;

straight level section of track will be provided for the purpose of spotting tank cars for unloading. In the event it is not possible to terminate the tank-car unloading spur track at the tank farm because of lack of room at the tank-farm site, excessive length of track required to reach the tank farm, or for other reasons, a separate site will be determined. Withdrawal of product from tank cars will be by means of 4-inch suction-type hose lines connected from the bottom outlet of the tank car to a 4-inch valved riser from an underground unloading header. With the exception of administrative gasoline and methyl alcohol, a 4-inch unloading connection at each tank-car unloading position will be provided for each grade of fuel to be received. When a single unloading track is provided, unloading headers will be installed along one side of the track with the unloading connections for each product at each tank-car unloading position arranged in groups at 40-foot intervals. Maximum distance between centerline of track and the unloading connection will be 10 feet. If two unloading tracks are provided, the unloading header will be installed between the tracks with one unloading connection for each product being provided for each tank car unloading position. One unloading connection will be provided for administrative gasoline at the last tank-car unloading position. One additional tank-car unloading position with one unloading connection will be provided for methyl alcohol. The unloading connection for each product will be distinctly marked for the product to be received. The unloading connections will be arranged in groups at each tank-car unloading position with the unloading connection for each product in the same relative position at each unloading position. The distance from the bottom of the track rail to the horizontal centerline of the unloading connection will not exceed 18 inches. For Air Force installations, the minimum size of the unloading headers will be 8 inches. Suitable racks will be provided for storing of the tank-car unloading hose when not in use.

b. Tank Cars and Tank Trucks. When delivery of product by tank trucks is required in addition to delivery by rail, a service road will parallel the tank-car unloading track. The road will have turnout pavement on the track side. The distance from the edge of the turnout pavement to the unloading connection will be not less than 5 feet nor greater than 10 feet. The distance from the top of the turnout pavement to the horizontal centerline of the unloading connection will not exceed

18 inches. The pavement at each unloading position will be level longitudinally but may have a transversal pitch. If two tank-car unloading tracks are required, the unloading connections for the track nearer to the roadway will be located on the roadway side of the track and duplicate unloading headers will be provided for the other track. If the anticipated volume of delivery by tank truck under the above conditions is substantial, sufficient additional unloading connections to provide unloading connections at 60-foot intervals will be permitted. Where delivery of product by tandem trailer is anticipated, duplicate risers for each product will be provided and spaced to permit simultaneous hose connections to the semitrailer tank and to the trailer tank. Spacing between unloading connections will be governed by the distance between the unloading connection on the semitrailer tank and on the trailer tank.

c. Tank Trucks Only. If delivery of product is by tank truck only, the spacing between unloading positions will be a minimum distance of 60 feet for single-tank units and as specified above for trailer trains. The size of unloading connections and headers, grouping and marking of unloading connections, the distance from the near edge of unloading pavement to the unloading connection, the distance from the top of the pavement to the horizontal centerline of the unloading connection, and the grading of the unloading pavement will be in accordance with applicable instructions for tank cars and tank trucks in the preceding subparagraphs under paragraph 4-05.

d. Unloading by Pump. When products are to be unloaded by pump, a pumphouse containing receiving pumping units, pipe manifolding, and related mechanical and electrical equipment will be provided. The pumphouse will be located in the proximity of the unloading area to minimize the length of the suction lines from the unloading connections. The pumphouse will not be located where long suction lines are required, or where the profile of the suction lines is interrupted by high points between the unloading connection and the pump suction port. The number of receiving pumps to be provided for each product and the arrangement of the receiving

pumphouse for Air Force air-base tank farms will be in conform-
* ance with applicable Standard Drawing No. 78-24-16, -17, -18, or -30. For Air Force area-reserve tank farms, the number of pumps for each product will be as authorized. The general arrangement of the receiving pumphouse for these installations will be as shown on Standard Drawing No. 78-24-23. The number of pumps to be provided for each product and general arrangement of facilities for other installations will be as authorized.

e. Gravity Unloading. Unloading of tank cars and tank trucks at Air Force water-alcohol systems and at Air National Guard or Army Aviation installations normally will be by gravity. Unloading lines for these facilities will be designed for a maximum unloading rate of 200 g.p.m., and will be so graded as to drain dry, with no intermediate high points. Other requirements will conform to applicable criteria contained in preceding subparagraphs of paragraph 4-5.

4-6. FACILITIES FOR RECEIVING PRODUCTS FROM CROSS-COUNTRY PIPELINE. Facilities to be provided for receiving products from a cross-country pipeline will include a pressure-regulating valve set to reduce the pressure in the cross-country pipeline to that compatible with the tank-farm-yard piping, duplex jet-type self-cleaning line strainers or a centrifugal-type solids separator with sump tank and auxiliary pump, block valves, line blinds, and pipe manifolding as required for segregation and distribution of products received via the pipeline. These facilities will be arranged so as to provide a block valve on the upstream and downstream sides of the pressure-regulating valve. The pressure-regulating valve and the upstream block valve and piping will be rated for the working pressure of the cross-country pipeline. The duplex jet-type self-cleaning line-strainer or centrifugal separator will be used for all products received from the cross-country pipeline, but strict product segregation will be maintained. This segregation will be accomplished by a manifold common to the strainer installation on one side and to the tank-farm lines on the other. Each tank-farm product line will be provided with a double-gated line blind at its connection to the manifold. All equipment and piping on the tank-farm side of the pressure-reducing valve will be rated for the working pressure of the tank-farm piping system. Facilities for sampling of products from the cross-country pipeline will be provided. Typical details for facilities of this nature are included in
* Standard Drawing No. 78-24-23.

4-7. FACILITIES FOR RECEIVING FUELS FROM BARGES AND MARINE TANKERS. When the fuels are to be delivered by barge or tanker, a single pipeline will be provided for light products such as aviation and automotive fuels, including No. 2 diesel fuel, and a single pipeline for heavy products such as numbers 4 and 6 diesel oils, Bunker C and Navy Special. A tank will be provided between the unloading facility and the tank farm, in order to segregate the product being received. Data on various sizes of tankers is tabulated in Department of Defense, Military Handbook 210, "Conversion Factors and Logistics Data for Petroleum Planning."

a. Barges. Sizing of pipelines from individual barges will be based on an unloading rate of 3,000 barrels per hour. When multiple-barge deliveries are to be anticipated, the sizing of the tank-farm fill headers and tank-fill branches will be based on the number of barges to be unloaded simultaneously. Dock facilities will be provided and will include dolphins and capstans for securing the barge, manually-operated davits for handling the unloading lines, and a chart house with telephone communications with the tank-farm administration building. Multiple docking and unloading facilities will be provided when multiple-barge tows are used. Unloading at barge docks will be by means of pumps installed on the barge and marine hose connected from the barge to the dock piping. Barge pumps will normally deliver to the barge hose connection at 125 p.s.i.g. Unloading piping at the dock will include flanged-end, swing-jointed fitted connections for attachment of the hose line, a manually-operated block valve on the downstream side of the hose-connection fitting, and a swing check valve on the downstream side of the block valve. The swing check valve will be positioned to prevent reverse flow from the tank farm, but will have an external operator that will permit opening of the valve when the product is to be outloaded to a barge from the tank farm. Flanged adapter spool pieces for the different-sized barge hose anticipated may be required. In such cases the flanged end for the connection with the barge hose will be faced and drilled to correspond with the facing and drilling of the flange on the barge hose. Blind flanges with bolts, nuts, and gaskets will be provided for closure of the flanged unloading connection when not in use The dock will be accessible to mobile or portable fire-fighting apparatus, and at least one water fire hydrant will be located at the shore end of the pier or dock. A typical barge-unloadin installation is included with Standard Drawing No. 78-24-23.

b. Marine Tankers. Sizing of pipelines for tanker unloading will be based on a maximum unloading rate of 12,000 barrels per hour at a pump discharge pressure of 80 p.s.i. Pier facilities, when required, will include necessary marine installations for securing the vessel, and power-operated rigs for handling the ship-to-shore unloading lines, and a pier house with telephone communications to the tank-farm administration buildin

Unloading at tanker piers will be by means of ships' pumps, with marine hose or power-operated flexible piping connected from the tanker to the pier piping. When power-operated flexible piping is provided, the shore installation will include a slop tank to receive drainage from those sections of the flexible piping that cannot be back-drained to the tanker after the unloading operation has been completed. The tanker pier will be accessible to mobile or portable fire-fighting apparatus, and water fire hydrants will be provided on the pier. A typical power-operated flexible-pipe unloading installation is included in Standard Drawing 78-24-23. Criteria for design of docks, piers and related marine items such as dolphins, capstans, and other shore facilities for mooring lines are not covered in this manual. Such design will be closely coordinated with the Civil Works Design Branch of the District having supervision, in order to provide a design capable of standing up under the local currents and weather conditions.

c. Submerged Sea Unloading Pipeline. When an unloading pier would not be economically feasible, a submerged sea unloading pipeline with a tanker mooring berth will be required. Before final selection of a site, investigation should include soundings, swell and wave heights, tidal rise, currents, sea bottom conditions, wind velocities, and maximum size of tanker that is expected to deliver fuel. The mooring berth will be of the mono-mooring type with mooring legs, or will be the 5-leg or 7-leg type, adequate for the largest expected tanker in the projected climatic and sea conditions. Mooring berth location will permit a minimum of 3/4-mile maneuvering distance around the berth, and will be arranged so that the tanker can make a direct approach to the berth without external assistance. The selection of the type of mooring desired will be coordinated with the operating using service, and with the Military Sea Transport Service whose contract carriers will deliver the fuel. The submerged pipeline shall be sized as described in subparagraph b above, and shall be of: steel, coated on the interior with a fuel resistant coating; or aluminum; or will be a noncorrosive fuel resistant material. Metal pipe will be coated on the exterior. The submerged pipeline will be anchored to prevent damage by tide or current action. Pipeline termination at the ships mooring end will be with a flange for attaching a hose manifold adapter. The hose manifold adapter will be provided with two flanged connections, one to attach the loading hose, and the other a spare. Suitable buoys will mark the anchors for berthing the tanker and the submarine hose attached to the end of the submerged pipeline where required. The length of chain connecting the buoys to the tankers and the submarine hose will be equal to 2-1/2 times the depth of the water at high tide. Since corrosion of submerged metal pipelines, especially in warmer waters and in the tidal range, is normally a serious problem, a thorough investigation of the requirements for

cathodic protection in addition to protective pipe wrapping and coating will be required. The entire tanker unloading system will be designed to provide a pressure of approximately 20 pounds per square inch at the suction manifold of the booster pump station or at the manifold of the most distant receiving tank.

4-8. FACILITIES FOR DISTRIBUTION TO HYDRANT-TYPE AIRCRAFT-REFUELING SYSTEMS. Distribution of the product from the tank farm to the operating storage tanks of hydrant-type aircraft-refueling systems will be by underground transfer pipelines. Separate transfer pipelines will be provided for each grade of fuel. Each pipeline will be sized to deliver 500 gallons per minute to each operating pumphouse. One 500 gallon per minute transfer pump will be provided for each operating pumphouse to be supplied, plus one standby pump for each product. If the transfer pipeline is longer than one mile, provisions will be made for inserting and retrieving pipeline cleaning equipment in the main portion of the transfer pipeline. The fill and withdrawal piping for the related product at the tank farm will be provided with a valved cross connection in the transfer pumphouse, and the fill and delivery piping in each operating pumphouse will be similarly cross connected in order to permit return of product from operating storage to the tank farm. Sectionalizing valve pits will be provided at the branch connection to each operating pumphouse. Manually-operated valves will be provided on the branch connection and on the transfer pipeline on the downstream (with respect to delivery from the tank farm) side of the branch-line connection. The block valve on the transfer pipeline will be omitted at the last connected operating pumphouse when there is no possibility of extending the transfer pipeline to future operating pumphouses. This block valve will be provided whenever future extension of the transfer pipeline is contemplated. In such cases the transfer pipeline will be extended to the outside of the sectionalizing valve pit and temporarily closed by means of a steel plate welded into the open end of the pipe. When transfer pipelines for different products pass by or extend to the branch connection to an operating pumphouse, provisions for switch-over of product will be incorporated in the design. This provision will be accomplished by means of a combination line blind and spectacle plate or a double block and bleed valve installed in the flanged joint of each pipe connecting the branch to a transfer pipeline. The combination line blind and spectacle plate or double block and bleed valve will be positioned to permit delivery from the transfer pipeline carrying the product to be dispensed at the operating pumphouse and to prevent delivery from another transfer pipeline.

4-9. FACILITIES FOR DISPENSING PRODUCTS AT TRUCK-FILL STANDS. The products to be dispensed at truck-fill stands and the number of fill stands to be provided will be determined by the using service. All truck-fill stands will be located a minimum distance of 30 feet from a pumphouse or filter/separator building and at least 100 feet from the shell of any aboveground fuel storage tank. Truck-fill

stands for Air Force installations will be as shown on
* Standard Drawings Nos. 78-24-16,-17, 18 and 30 for air base tank
* farms, No. 78-24-19 and 78-24-31 for underground tank farms, and No. 78-24-23 for area reserve tank farms. Piping and pumping equipment for each outlet at these fill stands will be capable of delivering 500 g.p.m. Truck-fill stands for Air Force water-alcohol systems will be as shown on Standard Drawing No. AW-78-25-01. Piping and pumping equipment for water-alcohol truck-fill-stand outlets will be sized for a delivery rate of 300 g.p.m. For Air National Guard installations the truck-fill stand will be as shown on Standard Draw-
* ings Nos. 78-24-16,-17, -18 and 30, but the delivery rate to each outlet will be 300 g.p.m. Truck-fill stands for Army Aviation facilities will be as shown on Standard Drawing No. 78-24-20. The delivery rate from each outlet of these fill stands will be 200 g.p.m.

4-10. FACILITIES FOR DISPENSING PRODUCTS AT THE TANK-CAR LOADING RACKS. When products are to be dispensed to railroad tank cars, a structural-steel framework with an open-grate platform at an elevation approximately 10 feet 6 inches above the top of the spur tracks will be provided. The length of the platform will be determined by the number of cars to be spotted for loading. A 4-inch counterbalanced tank-car loading-arm assembly with spring-loaded throttle valve and drop pipe approximately 10 feet long to reach to the bottom of the tank car will be mounted on a riser pipe at each tank car loading position. These positions will be 40 feet apart along both sides of the platform. A counterbalanced drop walkway with suitable guard rails will be provided at each loading arm position. The walkway will be of sufficient length to reach from the platform to the tank car dome. Access to the platform will be by stairways at both ends of the platform. Minimum clear distance between the tank car loading platform structure and the centerline of the spur track will be 8 feet 6 inches, this clearance to be increased as required to comply with local regulations. Other facilities to be provided on the tank car loading rack will include a small chart house for records and provisions for storing wetted blankets for smothering fires at tank-car domes. The riser for each tank-car-loading position will be connected by manifold to each of the several product supply lines, which will be run abovegrade below the platform. Combination line blanks and spectacle plates or double block and bleed valves will be used for the selection of the product at the particular loading arm. The spectacle plate will be installed between the flanges for the product to be delivered at this point, and the blanks will be installed between all other flanges. The filling rate for individual tank cars will be 500 g.p.m., the number of tank cars to be filled simultaneously with one product to be determined by the using service. Typical details of a tank-car loading rack are shown on Standard Drawing No. 78-24-23.

4-11. FACILITIES FOR DISPENSING PRODUCTS TO BARGE OR MARINE TANKER. When a tank farm is supplied by barge or marine tanker, facilities for dispensing products from the tank farm to the barge or tanker will be provided. This requirement will be met by means of a cross connection between the product-withdrawal piping and the receiving lines from the dock or pier. The arrangement of the cross connection will enable the tank-farm transfer pumps to deliver from the storage tanks to the vessel. Outloading delivery rates will be determined by the using service, and additional standby transfer pumps will be provided when the frequency of this operation warrants the installation of special transfer pumps.

SECTION 5. SPECIALIZED DISPENSING SYSTEMS

5-1. GENERAL. The principal functions considered in this section are those of dispensing aircraft- or vehicular-engine fuels from operating storage tanks directly into the fuel tanks of aircraft or vehicles or to aircraft refueler trucks. Such facilities include Air Force hydrant-type aircraft-refueling systems, supply for Air National Guard units, Army Aviation installations, and motor-pool and commissary service stations. Facilities for blending water and methyl alcohol and for dispensing the resultant mixture or straight alcohol to tank trucks are also covered in this chapter.

5-2. AIR FORCE MULTIPLE-OUTLET HYDRANT-TYPE AIRCRAFT-REFUELING SYSTEMS. The primary function of these systems is to deliver clean, dry fuel to the aircraft at its normal parking position. Each system basically consists of a pumping station with underground operating-storage tanks; underground piping and electrical power and control wiring from the pumping station to a number of valve and equipment pits, identified as hydrant-lateral-control pits; and a corresponding number of underground pipelines and electrical control circuits extending from these pits to refueling points on the apron. A hydrant-type refueling outlet and an electrical-control station are provided at each refueling point. A portable refueling cart with filter and meter equipment is used at this point for connecting the refueling-hydrant outlet to a single-point refueling fitting on the aircraft, by means of hose lines carried on the cart. This cart is identified as a filter/meter cart. These systems also provide for defueling of aircraft. Defueling is accomplished by using the aircraft-engine-feed and transfer pumps and one of the refueling-system defueling pumps to return fuel from the aircraft to operating storage. The latter pumps are also used to evacuate fuel from the filter/meter cart after the refueling or defueling operation. These systems are adaptable to large operational aprons for mass parking of aircraft, multimission aprons, aprons at operational service docks or wing hangars, or for dispersal
* stubs of staging air bases. Standard Drawings 78-24-01,
* 78-24-26, 78-24-28 and 78-24-29 are applicable.
Direction of pitch for under-apron hydrant lateral pipelines will be governed by the design of the apron and shoulder, but requirements for apron base course drainage and utilities under or along the apron will not be permitted to take precedence over the requirement for grading the hydrant-lateral pipeline, or maintaining minimum depth in the hydrant-lateral control pit. The design for all hydrant laterals installed for future activation will be carefully analyzed to make sure that they can eventually be extended to hydrant-lateral control pits without violating the depth limitation

or creating excessive static lift for the defueling pumps. When hydrant-lateral pipelines and electrical ducts are to be installed under aprons for future activation, or where certain refueling points of activated laterals are not to be activated, the refueling-outlet pit will be provided and the refueling-outlet piping stubbed 9 inches up from the bottom and closed by welding a 1/2-inch-thick plate to the end of the pipe. In such cases the electrical pull, receptacle, and switch box, complete, will be installed. Control conductors will not be installed for entire laterals not to be activated. However, control conductors will be connected at all points of laterals where only certain refueling points are to be activated. In all cases, the apron pavement will be placed around the refueling point without jointing between the raised section at the refueling point and the nearest continuous construction or dummy joint in the apron pavement. Electrical power and control systems; method of embedding the combination pull, receptacle, and switch box at the refueling point; and details of design for the refueling-hydrant-outlet pit will be as shown on the standard drawings. No departures will be permitted.

a. Medium Bomber System Capabilities. For these systems, a one-hydrant capability consists of 100,000 gallons of operating storage with 600-g.p.m. delivery-pump capacity, necessary filter/separators, delivery piping, and control pits. Thus, a three-hydrant pumphouse will have six 50,000-gallon-capacity tanks, six 300-g.p.m.-capacity pumps, and filter/separators and delivery piping sized to handle and dispense a total flow of 1,800 g.p.m. from the pumphouse. The rate of delivery from one hydrant outlet will be 600 g.p.m. at sufficient pressure to provide 100 p.s.i. (±5 p.s.i.) at the hydrant outlet, as measured at the downstream side of the hydrant coupler valve. A three-hydrant system will be capable of simultaneous delivery of 600 g.p.m. at this pressure through the most distant hydrant outlet of any three laterals supplied by that pumphouse. Each lateral will have defueling capabilities of 50 and 200 g.p.m. The number of hydrant capabilities and operating pumphouses and laterals to be supplied by the pumphouse will be determined by the using service. When these systems are required for 775-foot wide multimission aprons, the distance between lateral pipelines will be decreased from 293 feet to 161 feet, and alternating five-outlet and two-outlet laterals will be provided. Spacing of the outlets along the five-outlet laterals, as measured from the service-area edge, will be as shown on the standard drawings, except that the first outlet will be 35 feet 6 inches from the edge of the apron pavement. The two-outlet laterals will have one outlet in line with the second outlet of the five-outlet lateral, and a second outlet at the end of the lateral in line with the last outlet of the

five-outlet lateral. A hydrant lateral control pit will be provided for each of the activated five-outlet and two-outlet laterals. Activation of laterals and outlets in laterals will be as directed by the using service.

b. Cargo Aircraft System Capabilities.

(1) For C-141 aircraft. For the C-141 cargo aircraft, a one-hydrant capability consists of 150,000 gallons of operating storage with 900 g.p.m. delivery capacity, with necessary filter/separators, delivery piping, and dual hydrant outlets at each fueling point. A two-hydrant pumphouse will have six 50,000 gallon capacity tanks, six 300 g.p.m. capacity pumps, filter/separators, and delivery piping sized to handle and dispense a total flow of 1,800 gallons per minute from the pumphouse. The rate of delivery from one hydrant outlet will be about 450 g.p.m. from the dual hydrant outlets. A pressure of 100 p.s.i., plus or minus 5 p.s.i., will be provided at the dual hydrant outlets as measured from the downstream side of the hydrant coupler valve. The two hydrant systems will be capable of simultaneous delivery of 900 g.p.m. at the above pressure through the most distant dual hydrant outlet of any two laterals supplied by that pumphouse. Each lateral will have defueling capabilities of 50 and 300 g.p.m. The number of hydrant capabilities, operating pumphouses and laterals to be supplied by the pumphouse will be determined by the using service. It is the intent that this system be adaptable for use with the C-5A aircraft.

(2) For C-5A aircraft. For the C-5A cargo aircraft, a one-hydrant capability consists of 200,000 gallons of operating storage with 1,200 g.p.m. delivery capacity, necessary filter/separators, delivery piping, control pits and dual hydrant outlets at each fueling point. Thus, a two-hydrant pumphouse will have eight 50,000 gallon capacity tanks, eight 300 g.p.m. capacity pumps, filter/separators and delivery piping sized to handle and dispense a total flow of 2,400 g.p.m. from the pumphouse. The rate of delivery from one hydrant outlet will be approximately 600 g.p.m., 900 g.p.m., or 1,200 g.p.m. from the dual hydrant outlets, at a pressure of 100 p.s.i. plus or minus 5 p.s.i. measured from the downstream side of the hydrant coupler valve at the dual hydrant outlets. The two-hydrant system will be capable of simultaneously delivering 1,200 g.p.m. at the above pressure through the most distant dual hydrant outlet of any two laterals supplied by the pumphouse. Each lateral will have defueling capabilities of 50 and 300 g.p.m. The siting, the number of hydrant capabilities, operating pumphouses, and laterals to be supplied by the pumphouse, will be determined by the using service.

5-3. AIR FORCE SINGLE-OUTLET HYDRANT-TYPE AIRCRAFT-REFUELING SYSTEMS. Systems of this design provide a series of refueling outlets in line along the edge of a section of apron pavement designated to be used for refueling or defueling of aircraft. This makes it necessary to bring the aircraft to the outlet

for such servicing. Each system basically consists of a pumping station with underground operating storage tanks; underground piping and electrical power and control wiring from the pumping station to a number of valve and equipment pits, identified as filter/meter pits; and an underground pipeline and electrical control circuit from each pit to refueling points on the apron. A hydrant-type refueling outlet and an electrical control station are provided at each refueling point. These systems also provide for defueling by gravity flow from the aircraft to one of the system operating storage tanks, or to an underground tank specially installed for this purpose. Drawing No. 78-24-01 is applicable for this system; however, this system is not authorized for new construction.

5-4. CONVERSION OF SINGLE-OUTLET TO MULTIPLE-OUTLET HYDRANT-TYPE REFUELING SYSTEMS. When the requirement exists for the conversion of single-outlet hydrant-type refueling systems to the multiple-outlet hydrant type, the following procedure will be observed.

a. Filter/Meter Pits. Where filter/meter pits are not an obstruction to the aircraft outrigger wheels and gravity defueling can be obtained from the refueling-hydrant outlets in the new location, no change will be necessary to the filter/meter pit or equipment within. Where filter/meter pits are an obstruction to the aircraft outrigger wheels, new pits will be provided. The new filter/meter pit will be located between the aircraft parking stubs, in line with the new location of the refueling-hydrant outlets in the parking stub pavement. Where gravity defueling can be obtained at the newly located filter/meter pits and refueling-hydrant outlets, the existing filter/meter-pit equipment will be reinstalled in the newly located pits. Where gravity defueling cannot be obtained at the newly located filter/meter pits and refueling-hydrant outlets, the new pits will conform to the hydrant-lateral control pit shown on Standard Drawing No. 78-24-01, and the existing filter/meter equipment will be salvaged. All abandoned filter/meter pits will be demolished and filled.

b. Operating Pumphouses. The equipment in the existing operating pumphouse will not be changed except for the electrical controls necessary for proper operation when the multiple-outlet system equipment is installed. Conversion kits suitable for use with jet-engine fuel will be installed in the existing filter/separators. When additional fuel-storage and pumping capacity are authorized, the existing pumphouse will be modified to include the additional facilities provided it is economically feasible. When modification of the existing pumphouse cannot be economically justified, a new pumphouse with new hydrant-lateral control pits and new refueling-hydrant

outlets will be provided. These facilities will be as shown on applicable standard drawings for multiple-outlet hydrant-type systems.

c. Refueling-Hydrant Outlets and Electrical Controls. These facilities will conform to applicable standard drawings for single-outlet hydrant-type refueling systems, except when the system is to be modified to a multiple-outlet system. Cutting of existing pavement to provide for locating refueling-hydrant outlets in the stub-parking area will be permitted. Taxiway pavement may be cut to allow for the proper installation of the piping for the refueling-hydrant outlets in stubs on the opposite side from the pumphouse. Cutting of pavement to provide for the installation of the first refueling outlet in from the edge of mass-parking-apron pavement will be permitted. Where connections to existing piping will occur under pavement, the new pipe will be of the same material as the existing pipe. Where no pipe exists, the new pipe will be aluminum. Joints between dissimilar metals will be insulated and protected to retard galvanic action. Such joints will not be installed under pavement or buried in unpaved areas. Where gravity defueling is not possible, all filter/meter pits and refueling-hydrant outlets connected to the same pumphouse will be connected to the multiple-outlet hydrant system.

5-5. HYDRAULIC DISPLACEMENT SYSTEM. The hydraulic displacement system relies on the displacement of the fuel by water in a closed pressure tank under controlled conditions. The rate of flow of fuel from the tank is governed by the pressure at which the water is introduced and the total head in the fuel-dispensing system to be overcome. These systems are presently being used to a limited extent to dispense automotive gasoline to truck-fill stands.

a. Operating Tanks. Operating tanks for these systems will be as described in preceding paragraph 3-5b. If a hydraulic-displacement system is authorized, each tank will require special valves and fittings to control the flow of the product and to prevent delivery of water from the tank.

b. Accessories. The product delivered from such tanks will be delivered through a specially fitted vessel designed to trap any water carried out of the tank with the product. This tank will be fitted with a fuel-entrance connection consisting of a float-operated valve designed to close on rise of water level from the bottom of the vessel. Fuel will be discharged through a second connection in the top of the tank. A stick gage and water-removal riser extending up from an opening in the top of the tank will be provided.

c. Installation. These systems will be installed underground with the various tank fittings and appurtenances in one or more pits. The system will be supplied either as a self-sustaining operating unit, or from aboveground bulk-storage tanks.

5-6. WATER-ALCOHOL SYSTEMS. Power augmentation at takeoff is achieved in some types of jet-engine aircraft by injection of a water and methyl alcohol mixture into the engine-fuel supply system. A different blend of water and methyl alcohol is used in piston-type aircraft. When facilities of this nature are required, they will consist of a pumphouse, one underground tank for storage of straight alcohol, and an underground tank for mixing and blending the alcohol with water. Facilities for dispensing the water-alcohol mixture and straight alcohol at truck-fill stands will be provided. Each straight-alcohol tank will have a 150-g.p.m.-capacity pump for transferring this product to the blend tank or for delivery to the truck-fill stand. Each blend tank will have a 300-g.p.m.-capacity pump for circulating and blending or for delivery of the blend to another truck-fill stand. Provisions for the introduction of water and additives necessary to the water-alcohol mixture will be incorporated in the design of the blend tank. These will include a break between the water-supply piping and the water-fill stem to prevent backflow of the blend-tank contents into the water-supply piping. Volumetric displacement-type meters will be provided for measuring alcohol. The facility will be located in the tank-farm area where it can be served by utilities available at that location. Standard Drawing No. AW-78-25-(provides one 25,000-gallon-capacity tank for storing alcohol and one 25,000-gallon-capacity tank for mixing and blending the alcohol and water, and is applicable to single-wing Air Force bases.

5-7. AIR NATIONAL GUARD TRUCK-FILL-SYSTEM INSTALLATIONS. Authorizations usually require 100,000 gallons of underground fuel storage. Operational requirements usually specify this storage to be entirely for jet fuel or may be for both aviation gasoline and jet fuel. The fuel will be stored in four 25,000-gallon-capacity underground tanks with a deep-well-type dispensing pump for each tank. **A separate piping system will be provided** for each grade of fuel. The size and capacity of this equipment and method of receiving and dispensing will be as specified in Section IV. When the entire fuel storage is for jet fuel, two truck-fill stands will be provided. When the fuel requirements are for two grades, two truck-fill stands will be provided for jet fuel and one for

aviation gasoline. One 300-g.p.m.-capacity meter with flow controller will be provided at each fill stand. Pumphouses will be as described in paragraph 3-6.

5-8. ARMY AVIATION TRUCK-FILL SYSTEM. Standard Drawing No. 78-24-20 is applicable to these fueling systems. Fuel will be stored in underground horizontal tanks. The number and size of the tanks will be based on the requirements of organic and transit aircraft as established by the operating agency. The tanks will be supplied by tank car or tank trucks via gravity unloading lines. Fuel pumps will be installed aboveground in the proximity of the tanks and will be capable of delivering 200 g.p.m. to the fill stand. Filter/separators of 300-g.p.m. capacity will be provided for each grade of fuel and will be installed in a shelter or heated building as described in paragraph 3- 6. One fill stand will be provided for each grade of fuel and will be as described in paragraph 3- 9 except that no meter will be installed.

5-9. VEHICULAR-ENGINE-FUEL SYSTEMS. Facilities for supplying automotive fuel will consist of a motor-pool service station for military vehicles and a commissary service station for vehicles owned by personnel.

a. Motor-Pool Service Stations. A motor-pool service station will consist of at least one underground storage tank for each grade of fuel and one or more noncomputing-type commercial dispensing pumps installed on a typical service-station island. The number and capacities of tanks to be provided and the number of dispensing pumps will be determined as described in TM 5-800-1. The dispensing pumps for such facilities will have a capacity of 12-15 g.p.m. for passenger cars and 22-25 g.p.m. for trucks, buses, and tracked vehicles. A separate suction line will be provided for each pump.

b. Commissary Service Stations. Commissary service stations will frequently be constructed by a commercial oil company that has secured the franchise for furnishing this service to the base. The size and capacity of the commissary service station will be determined as described in TM 5-800-1.

5-10. ELECTRIC POWERPLANT DIESEL FUEL STORAGE. Diesel fuel storage for electric generating plants will normally be in underground storage tanks adjacent to the powerplant. However, where the quantity of fuel to be stored is so great that storage entirely underground would be too costly or require too much construction time, aboveground storage will be considered after determining available space, safety clearances, security requirements, and underground construction conditions. The fuel storage capacity will be based on estimated average demand, and will be equivalent to 15 days supply when delivery is readily available, or 30 days supply at remote locations.

5-11. HARDENING OF AIRCRAFT-REFUELING FACILITIES. Where there is a requirement for the construction of hydrant-type aircraft-refueling facilities capable of withstanding an overpressure of 10 p.s.i. resulting from an atomic blast, the design of the pumphouse and operating storage tanks and the hydrant-lateral control pits will conform to Standard Drawing No. 78-24-21.

5-12. HARDENING OF EXISTING ABOVEGROUND TANKS. Where hardening is authorized for the protection of existing aboveground tanks to resist the effect of an overpressure of 10 psi resulting from an atomic blast, the design will conform to Standard Drawing Nos. 78-24-09 thru 13.

5-13. HARDENING OF EXISTING TRANSFER PUMPHOUSES. Where hardening is authorized for the protection of existing transfer pumphouses at tank farms to resist the effect of an overpressure of 10 p.s.i. resulting from an atomic blast, the design will conform to Standard Drawing No. 78-24-22. For new construction of transfer pumphouses to resist the effect of an overpressure of 10 p.s.i. resulting from an atomic blast, the design will conform to Standard Drawing No. 78-24-25.

SECTION 6. DATA FOR PIPING SYSTEMS

6-1. FLOW OF LIQUIDS IN PIPES. Visual studies of the flow of liquids in transparent piping where the behavior of the liquid could be observed disclose that an increase or decrease in the velocity at which the liquid is moving through the pipe results in two characteristic types of flow for any given liquid at a given temperature. These types of flow are defined as follows:

a. Viscous Flow. When the velocity is reduced below a certain critical point the liquid flowing through the pipe is carried along in a relative straight path without any notable rotating or swirling motion. This type of flow is called viscous flow and the velocity of the liquid is greatest at the center of the pipe, decreasing rapidly to zero at the wall of the pipe with concentric cylinders of the liquid flowing past one another. When the flow is viscous there is practically no friction between the liquid and the pipe.

b. Turbulent Flow. As the velocity of the liquid is increased, a point is reached where the flow begins to change to an irregular rotating or swirling type of flow and the velocity becomes more constant throughout a cross section of the liquid. This type of flow is called turbulent flow; and, though there still remains a thin layer of the fluid at the pipe wall that continues to flow in a straight line, or viscous flow, the roughness of the pipe wall now has a very marked effect on the flow, resulting in a loss of pressure due to friction between the liquid and the wall of the pipe. Except when it becomes necessary to handle extremely viscous liquids, economical selection of pipe sizes will normally result in the flow's being turbulent.

c. Relative Factor of Friction. The relative factor of friction for a given condition has been arrived at experimentally and is related to the size of the pipe, the viscosity and density of the liquid, and the velocity of the liquid. The numerical value of a dimensionless combination of these four items is known as Reynolds number and it is necessary to calculate the Reynolds number for any given condition before the friction factor can be determined.

6-2. FRICTION FACTOR. Knowing the type and size of the pipe, the velocity or rate of flow, the viscosity and dens y, or the kinematic viscosity, of the liquid, it is possible calculate the representative Reynolds number, and from thi information determine whether the flow will be viscous or turbulent and what the corresponding friction factor will be by proceeding as follows:

a. Formulas for Reynolds Number. Any of the formulas listed below may be used to determine the Reynolds number, where

U = absolute viscosity in centipoise
B = flow in barrels per hour
Den = density in pounds per cubic foot
Q = flow in gallons per minute
D = inside diameter of pipe in inches
K = Kinematic viscosity in centistokes = $\frac{U}{Den}$
R = Reynolds number

$$R = \frac{3,162 \times Q}{D \times K}$$

$$R = \frac{2,214 \times B}{D \times K}$$

$$R = \frac{50.7 \times Q \times Den}{D \times U}$$

$$R = \frac{35.5 \times B \times Den}{D \times U}$$

Figure 8 at the end of this section may be used for determ ing the Reynolds number for the listed pipe sizes without the e of formula.

b. Friction Factor for Viscous Flow. In computing fri ion losses for liquids flowing in pipes it is common practice consider the flow to be viscous when the Reynolds number i 1,200 or less. In such cases the friction factor is assig d a value of 64 divided by the Reynolds number. $F = 64/R$.

c. Friction Factor for Turbulent Flow. For Reynolds number values above 1,200 there is a transitory region extending to somewhere between 2,200 and 3,000 where the flo

changes from viscous to turbulent and where the flow may be either viscous or turbulent depending on the condition of the flow as it enters that section of the pipe, and to a degree upon the roughness of the pipe. Except in the case of very viscous liquids, it is considered good design to assume the flow to be turbulent in this region. The flow will definitely be turbulent for Reynolds numbers of higher value. Figure 9 at the end of this section will be of assistance in determining the friction factor for turbulent flow.

6-3. FRICTION LOSSES IN PIPES. The loss of pressure resulting from friction created between the pipe and the liquid flowing within the pipe is called the friction loss. This loss may be expressed in terms of pounds per square inch of pressure within the pipe, or in feet as related to a column of the liquid of sufficient height to create a pressure equivalent to the loss in pounds per square inch. When used to define the service required of a pumping unit to move a liquid through a piping system the friction loss is usually expressed in feet of head. Depending on the information available, the friction loss may be calculated by means of any of the following formulas, all of which make allowance for the effects of the viscosity of the liquid on the friction loss. These are all based on a formula known as Fanning's equation, which was derived from Bernoulli's theorem.

a. Formulas for Friction Loss in Feet of Head. Where

B = flow in barrels per hour
F = friction factor
Q = flow in gallons per minute
H_f = friction loss in feet of head
D = inside diameter of pipe in inches
L = length of pipe in feet

$$H_f = \frac{.03112 \times F \times L \times Q^2}{D^5}$$

$$H_f = \frac{.0153 \times F \times L \times B^2}{D^5}$$

b. Formulas for Friction Loss in Pounds per Square Inch.
Where

B = flow in barrels per hour
Den = density in pounds per cubic foot
F = friction factor
Q = flow in gallons per minute
D = inside diameter of pipe in inches
L = length of pipe in feet
P_f = friction loss in pounds per square inch

$$P_f = \frac{.000215 \times F \times L \times D \times Q^2}{D^5}$$

$$P_f = \frac{.000106 \times F \times L \times D \times B^2}{D^5}$$

c. Typical Use of Formula. Grade JP-4 fuel having a specific gravity of 0.77 and a kinematic viscosity of 1.20 centistokes must be delivered through a schedule 40 six-inch pipeline 5,000 feet long at 600 g.p.m. The friction loss under these circumstances can be calculated as follows:

$$\text{Reynolds No.} = \frac{3,162 \times 600}{6.065 \times 1.2} \text{ or } 260,676$$

From the friction factor chart in Figure 9, it is noted that the related friction factor is 0.0172. With this information it can be determined that the friction loss will be

$$\text{Friction Loss} = \frac{0.03112 \times 0.0172 \times 5,000 \times 36,000}{8,206} \text{ or } 117.50 \text{ feet}$$

The pipe-flow chart, Figure 10 at the end of this section, may be used to determine pressure drop due to pipe friction, and following Figures 11 and 12 contain information concerning pressure drop through welding fittings and plug valves.

6-4. VELOCITY HEAD. In addition to the friction head, it is necessary to know the velocity head when determining the total head to be overcome by a pumping unit. One definition for velocity head is the vertical distance a body would have

to fall to acquire the velocity of the flowing liquid. Velocity head is also defined as that portion of the energy of the flowing liquid that is due to its velocity. This corresponds to the static head that would cause that velocity. Velocity head may be determined by use of any of the following formulas, where

H_v = velocity head
V = velocity of flow in feet per second
Q = flow in gallons per minute
B = flow in barrels per hour
D = inside diameter of pipe in inches
G = acceleration due to gravity in feet per second. At sea level and 45° latitude this is 32.174 ft. per second and this value has been used in conversions.

$$H_v = \frac{V^2}{2G} = 0.0155 \times V^2$$

$$H_v = \frac{0.00259 \times Q^2}{D^4} = \frac{0.00127 \times B^2}{D^4}$$

6-5. STATIC HEAD. As applied to a pump, static head is the vertical distance in feet between the free level of the source of supply and the point of free discharge. The static suction lift is the vertical distance in feet from the level of the free source of supply to the centerline of the pump when the pump is above the source of supply. The static suction head is this distance when the pump is below the source of supply; or, in the case of delivery under pressure, is the difference in feet between the level corresponding to the pressure and the centerline of the pump.

6-6. NET POSITIVE SUCTION HEAD. Net positive suction head is the total head in feet of liquid, including velocity head, available at the entrance to centrifugal pumps in excess of the vapor pressure of the liquid at pumping temperature. For horizontal centrifugal pumps the reference datum is the centerline of the pump intake port; in vertical centrifugal units, the eye of the suction of first-stage impeller.

a. Formula for Net Positive Suction Head. Available net positive suction head can be calculated as follows, where

A = atmospheric pressure in feet of liquid absolute. (See Figure No. 14 at the end of this section.)
H_{ss} = static suction head in feet
L_s = static suction lift in feet of head
H_{sf} = suction friction head in feet

V_p = vapor pressure of liquid in feet of liquid, absolute.

For installations where the suction source is above the pump:

$$NPSH = A + H_{ss} - H_{sf} - V_p$$

For installations where the suction source is below the pumps:

$$NPSH = A - L_s - H_{sf} - V_p$$

b. Required Net Positive Suction Head. The design of the centrifugal-pump impeller and casing are important factors in the internal pump losses that determine the required NPSH. Other significant factors are the liquid velocity at the eye, the peripheral velocity at the eye, the eye area and the pump speed. The required net positive suction head can be furnished by the pump manufacturer and in all cases must be smaller than the available net positive suction head in order for the pump to perform as desired.

c. Typical Use of Formula. Grade JP-4 fuel having a specific gravity of 0.77 and a Reid Vapor Pressure of 2.50 p.s.i. at pumping temperature is to be used at an altitude of 1,000 feet above sea level. The velocity head is 1.00 foot, the friction loss in the suction piping is 14 feet, and the static suction head is 6 feet.

A = 14.70 - 0.50 = 14.20 p.s.i.

$14.20 \times \frac{2.31}{0.77} =$ 42.60 feet

H_{ss} = 6.00 feet

H_{sf} = 14.00 feet

H_v = 1.00 foot

$V_p = \frac{2.50 \text{ p.s.i.} \times 2.31}{0.77} =$ 7.50 feet

NPSH = 42.70 + 6.00 - 14.00 - 1.00 - 7.50 = 26.20 feet

6-7. HORSEPOWER REQUIRED OF PUMP MOTOR. The actual, or brake, horsepower required of a pump motor can be calculated as follows, where

BHP = brake horsepower
Q = gallons of liquid pumped per minute
H = total head, in feet of liquid
W = weight of liquid in pounds per gallon
E = mechanical efficiency of pump

$$BHP = \frac{Q \times W \times H}{33{,}000 \times E}$$

Thus grade JP-4 fuel having a specific gravity of 0.77 and a weight of 6.42 lbs. per gallon to be pumped at a rate of 500 g.p.m. at a total head of 240 feet by a pump with mechanical efficiency of 65% will require a motor with brake horsepower rating as follows:

$$BHP = \frac{500 \times 6.42 \times 240}{33{,}000 \times 0.65} = 35.90$$